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OF THE

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UNIVERSITY OF TORONTO

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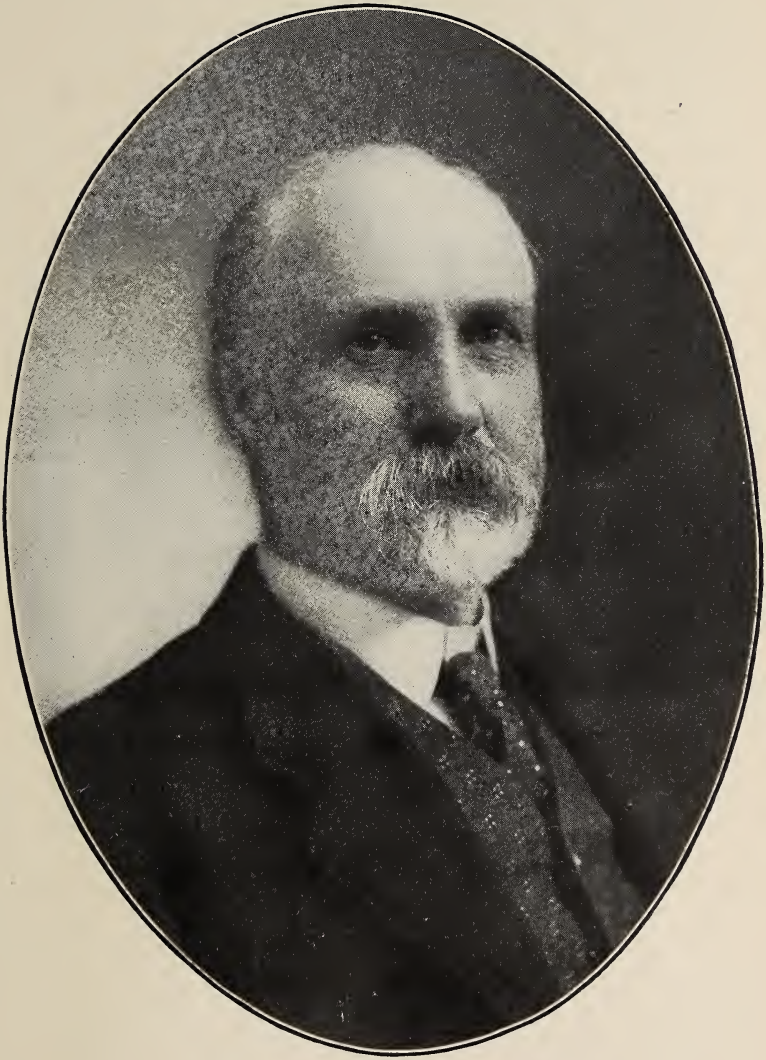

A. P. Coleman

PREFACE.

The twentieth volume of the Transactions of the Engineering Society of the Ontario School of Practical Science, now the Engineering Society of the University of Toronto, is offered to our readers as a record of part of the work accomplished by the Society during the session just closed.

A programme of the meetings of the year is printed elsewhere.

We take pleasure in presenting our readers with a portrait of Dr. A. P. Coleman, Professor of Geology, one of our honorary members.

The Society wishes to tender its thanks to all who contributed.

The present edition contains 2,750 copies.

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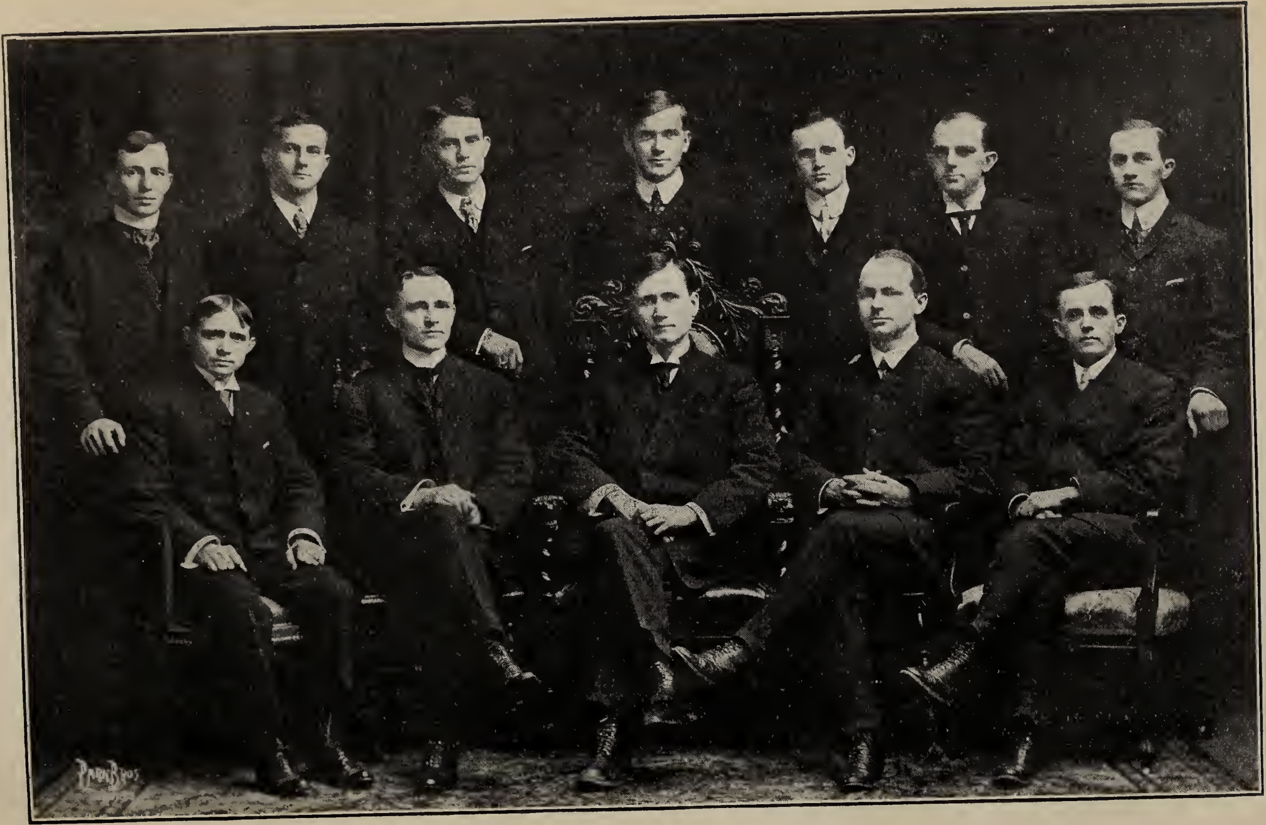

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Wilson, L. Z., '09.
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Wookey, S. A., '09.

T. KENNARD THOMSON, C. E.

A BIOGRAPHY OF WHOM APPEARS ELSEWHERE.

A. P. COLEMAN, M.A., Ph.D.

Arthur Philemon Coleman was born in the village of Lachute, in the Province of Quebec, on the 4th of April, 1852. His father was the Reverend Francis Coleman, a native of England, and a well-known and highly esteemed minister of the Methodist Church. His mother, Emmeline Maria Adams, was a descendant of the U. E. L. branch of the Adams family who had settled in New England in the seventeenth century. Her sister, Miss Mary E. Adams, was widely known as an eminent educator, and a woman of rare intellectual and artistic gifts; and after Mrs. Coleman's early death she extended a mother's affectionate care to her sister's orphaned children.

Mr. Coleman received his preparatory training in the public and high schools of Ontario, and after a brief apprenticeship as a teacher in a public school, he entered Victoria College as an undergraduate of the first year in the autumn of 1872. At matriculation he won the Mark Bursary, and at the end of the year the first place in Classics with the Mills Prize, and the Wallbridge Prize in Greek Testament. At the end of the second year he won the first place in the examination for the Biggar Scholarship, covering English, Classics, and Natural Science, and next the Webster Prize in English Composition at the end of the third year. At graduation he was bracketed with Mr. James Smith, for the Prince of Wales Gold Medal, the highest honor of the year—his subjects being Classics, Physics, Science and French. Immediately after graduation he was appointed Classical Master in the Cobourg Collegiate Institute. He also commenced a course of post-graduate studies in Science in the laboratory of Faraday Hall, under Dr. Haanel, now the Dominion Superintendent of Mines, and secured the M.A. degree in 1880. He next proceeded to Germany and continued his scientific studies in the University of Breslau, where he received the degree of Ph.D., *cum laude,* in 1882. His major subject was Geology, his dissertation was on "The Melaphyrs of Lower Silesia," and his minors were Mineralogy and Chemistry. Ten years later he again visited Germany and spent a year in the study of Metallurgy in the famous School of Mines at Freiberg. While in Europe his vacations were spent in field work in Bohemia, Switzerland and Scandinavia.

On his return to Canada he received the appointment of Professor of Geology and Natural History in Victoria University, which he held till 1891, when, after the federation of Victoria with the University of Toronto, he was transferred to the staff of Applied Science and Engineering in the Provincial University, and on the resignation of Prof. Chapman was appointed professor of Geology in the faculty of Arts. Since his appointment the work has grown until it now occupies the full time of two professors, an associate professor and two assistants, with a Curator of the Museum.

Dr. Coleman is distinguished not only for his extensive scientific attainments, but also for his rare literary gifts, and is exceedingly popular as a writer and public lecturer on scientific subjects. His field work in Geology has covered the whole region of New Ontario east and west, and the Rocky Mountains from the boundary line to the Yukon. As he is still in the prime of life the University may hope from him for many years valuable service.

PROGRAMME OF REGULAR MEETINGS, 1906-7.

October 10th, 1906—
  Prof. Coleman, "Geological Trip through Mexico."
  Mr. E. L. Cousins, '06, "Irrigation in Alberta."
  Mr. J. M. Wilson, '07, "City Water Tunnel."

October 24th, 1906—
  Mr. P. Gillespie, "Water Power Development at Niagara Falls."

November 8th, 1906—
  Debate on "Type of Construction for Panama Canal."
    Messrs. Near, '06; Lepan,'07; McGugan, '07; Challen, '08; Brecken, '08, and Vogan, '09.

November 22nd, 1906—
  Prof. Rosebrugh, "Engineering Ethics."
  Mr. W. McLaughlin, '06, "Shop Work for Mechanical and Electrical Engineers."
  Mr. M. P. Death, '06, "Repairing Dynamos and Motors."
  Mr. T. H. Hogg, '07, "Coffer Dams for Ontario Power Co., at Niagara Falls."

December 6th, 1906.
  Mr. S. Gagné, "Advice to Young Engineers."

January 17th, 1907—
  Mr. T. H. Hogg, "Electric Power Transmission."

January 30th, 1907—
  Mr. Vickers, '06, "Steam Turbines."
  Mr. W. F. Scott, "Engineering Features in Connection with Royal Alexandra Theatre."

February 14th, 1907—
Mr. C. H. Mitchell, "Hydro-Electric Development in Europe."

February 22nd, 1907—
Special meeting for consideration of new constitution.

February 27th, 1907—
New constitution amended and adopted.
Mr. T. Kennard Thomson, "Pneumatic Caissons."

March 6th, 1907—
Special meeting.
Mr. Reg. Hagarty, '07, "Railroad Terminals."

March 13th, 1907—
Nominations.

March 19th, 1907—
Mr. John M. Ewen, "Modern Building Construction from Standpoint of Engineer-Constructor."

March 27th, 1907—
Mr. S. Dushman, "Electric Metallurgy of Iron and Steel."
Mr. F. R. Smith, "Georgian Bay Canal."

EXCHANGES.

Ontario Land Surveyors, Toronto, Report, 200 copies.

Michigan Engineering Society, Climax, Mich., Michigan Engineer, 135 copies.

Engineering Society, University of Illinois, Champaign, Ill., Technograph, 125 copies.

Association of Civil Engineers, Cornell University, Ithaca, N.Y., Transactions, 125 copies.

Engineering Society, University of Michigan, Ann Arbor, Michigan Technic, 150 copies.

Purdue Society of Civil Engineers, Lafayette, Ind., 100 copies.

Colorado School of Mines, Golden, Col., 100 copies.

University of Colorado, Boulder, Col., Journal of Engineering, 60 copies.

Ontario Association of Architects, Toronto, Ont., 40 copies.

University of Toronto Studies, Toronto, Ont.

Ontario Historical Society, Education Dept., Toronto, Ont.

Bureau of Mines, Toronto, Ont.

Geological Survey of Canada, Ottawa, Ont.

Queen's University, Kingston, Ont.

Canadian Society of Civil Engineers, Montreal, P.Q.

Canadian Mining Institute, Nova Scotia, Can.

Association of Engineering Societies, Philadelphia, Pa.

Pratt Institute, Brooklyn, N.Y.

Rensallaer Society of Engineers, Troy, N.Y.

Columbia University, New York, N.Y.

Indiana Engineering Society, Indianapolis, Ind.

American Society of Civil Engineers, New York, N.Y.

United States Coast and Geodetic Survey, Washington, D.C.

United States Tests of Metals, etc., Washington, D.C.

Patent Office, London, Eng.

Institution of Mechanical Engineers, London, Eng.

Royal Institution of British Architects, London, Eng.

Society of Chemical Industry, London, Eng.

Institution of Junior Engineers, London, Eng.

Institution of Engineers and Shipbuilders, Glasgow, Scotland.

Societé des Ingenieurs Civils de France, Paris, France.

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ENGINEERING SOCIETY

OF

The University of Toronto

TORONTO.

PRESIDENT'S VALEDICTORY.

GENTLEMEN:—

This is the last time I shall have the opportunity of addressing you as your President. It gives me the greatest pleasure to thank you for your hearty co-operation throughout my term of office. It is gratifying to think that the same enthusiasm which is so characteristic of the "School" in athletics has been carried into our Society, and that the attendance at our meetings has been limited only by the accommodation available (300 seats).

All our college functions and enterprises have been uniformly successful, have more than kept pace with the phenomenal growth of the Faculty of Applied Science.

The business of the Society has grown to such magnitude and has become so complex that it is almost impossible for the chief executive officers of the Society to do justice to their academic work, and at the same time properly carry out the duties of their offices. No man should accept any office who will not give his very best efforts to the same. For this reason, and also to endeavor to secure better results in the matter of discussion of papers, the Society has been sub-divided. This will permit of the discussion of papers of peculiar interest to the several departments. It is to be hoped that the arrangement will work out so as to secure more elasticity without impairing the strength of the Engineering Society.

You have approved of the idea of having a permanent Secretary, who will devote most of his time to the interests of the student body. It is more than probable that before you assemble in the fall, the details will be worked out and an appointment made.

The business of the Society has exceeded that of any previous year. Your committee, however, concluded that it was not good policy to continue piling up a surplus. A considerable reduction in the price of supplies was consequently made. With the appointment of a Secretary the Society will be able to go more extensively into the sale of supplies, and a further cut may be confidently expected.

The relations between the student body and the staff have been most cordial. The only real grievance in existence is the overcrowded condition of the buildings. More space for drafting and more laboratory accommodation for engineering work proper, are urgently required. It is anticipated that the Board of Governors of the University will take immediate action in the matter.

Much has been accomplished this year. Credit should go where it belongs. Too much approbation cannot be given to the most loyal and able executive committee with whom it has been my lot to work. It is very rarely a president is fortunate enough to have such a reliable committee, and to them most of the credit belongs.

In conclusion let me thank you for the honor you have done me—an honor which I have always striven to merit.

I have much pleasure in presenting to the Society their President-elect for 1907-'08, Mr. T. H. Hogg.

Yours sincerely,

Ken. A. MacKenzie.

T. KENNARD THOMSON.

T. Kennard Thomson, '86, was born in Buffalo in 1864. He is the son of the late Wm. Alex. Thomson, founder of the Canada Southern R. R., who, at the time of his demise in 1878, represented the County of Welland in the Canadian House of Commons.

It was while a second year student at the School of Practical Science that Mr. Thomson first conceived the idea of founding an Engineering Society. The consensus of opinion among the students at that time seemed to be that the student body was too weak numerically to attempt such an undertaking. Thomson, however, thought otherwise. Some time during that year he invited the second and third year classes, Professor Galbraith, Doctor Ellis and a few outside friends, to take supper with him, and there took advantage of the opportunity to suggest the starting of an Engineering Society. All present enthusiastically indorsed the scheme, and a committee was appointed on the spot to draft a constitution. About the same time, Mr. H. J. Bowman, '85, had introduced an engineering display at the annual conversazione. The two joined forces and the Engineering Society of the School of Practical Science was launched on its career.

It is a source of gratification to older graduates, among them Mr. Thomson, that the Society has, for twenty-two years, continued to extend its sphere of usefulness. It has never halted in its march, and the outlook at the present time is brighter than ever before.

The three summers prior to graduation Thomson spent on the Canadian Pacific in the Rocky Mountains, and the two years immediately after graduation, with the Dominion Bridge Co. of Montreal. He then considered that he could do better in the States and went to New York on "spec." After four days spent in looking around the great metropolis, he met the Chief Engineer of the Pencoyd Bridge Co., and engaged with him to enter the employ of this corporation at Pencoyd, Pa. This position he retained until the following spring (1889), when he resigned in order to visit the Paris Exhibition with the American Society of Civil Engineers. He remained abroad four months and after his return was re-engaged by his old employers at a substantial advance in salary. This position he held until his former chief on the C. P. R. offered him the position of Bridge Engineer on the Ohio extension of the Norfolk and Western Railway. This involved the design and erection of one hundred and twenty-nine bridges, including the big one over the Ohio River at Kenova, West Virginia.

In 1891 he accepted a position as Superintendent of Bridges for Mr. Chas. M. Jacobs, Consulting Engineer, for whom he rebuilt several bridges and reported on many others. Following this, he was engaged by the Yale and Torone Mfg. Co. of Stamford, Conn., for about a year, during which time he made a series of standard designs for electric travelling cranes, etc.

Thomson then became Chief Engineer of a highway bridge company, and after its failure became Principal Assistant Engineer to his old chief, Mr. Jacobs, his special charge being the proposed Blackwell's Island Bridge. After two piers had been completed to above high water and the plans for 80,000,000 pounds of bridge steel had been approved, matters came to a standstill owing partly to stringency in the money market and partly to the death of Mr. Austin Corbin, President of the Long Island Railroad, for whom the bridge was being constructed. The work has never been resumed. Mr. Thomson was then engaged by Arthur McMullen & Co., a large firm of foundation contractors, to make the plans for and supervise the construction of the Commercial Cable foundations on Broad Street, New York City. This marks the beginning of deep cellar foundation construction in New York. The foundations were carried about 30 feet below water in this instance, and the cellar floor was placed 16 feet below water.

He was Engineer for this firm for about eight years, during which time they constructed the Mutual Life Building, foundations with a cellar thirty-two feet below water, some of the column foundations being carried 100 feet below the street, or 85 feet below water; the addition to the Manhattan Life, etc., etc.; the big stone ten-span arch bridge, eighty feet wide and twelve hundred feet long, at Hartford, Conn.; the caissons for the Monongahela Bridge at Pittsburg; Mingo Junction Bridge, Ohio; the Havre de Grace Bridge and many others.

About 1893 Mr. Thomson started doing work as a Consulting Engineer, and most of his salaried engagements since that time have permitted him to continue his private practice. He has made designs for coaling stations, elevated stations, bridges of all kinds, cable ways, train sheds, pneumatic canal locks, underground railroads and all kinds of contractors' plants. He has designed many pneumatic caissons and has been in the air chamber over two thousand times. He has been retained in the consulting capacity on over a dozen New York sky scrapers; has acted as arbitrator in law suits and has been in the expert witness chair on many occasions. He has taken out several tunnel, lighthouse and other patents.

Mr. Thomson married the third daughter of the late Mr. Arthur Harvey, F.R.S., of Toronto, and is the proud possessor of two daughters and three sons. He has been a frequent contributor to our "Papers," as well as to the current technical press. He is a member of the American Society of Civil Engineers, the Canadian Society of Civil Engineers, the Engineers' Club of New York, the National Geographical Society of Washington, the American Forestry Association, the Upper Canada College Old Boys' Association, and a life member of the Niagara Historical Society. He is also, this year, President of the Toronto University Club of New York, and last, but we trust not least, a life member of the Engineering Society of the School of Science, in which he has always felt and manifested a real paternal interest.

SOME NOTES ON PNEUMATIC CAISSONS FOR BRIDGES AND BUILDINGS.

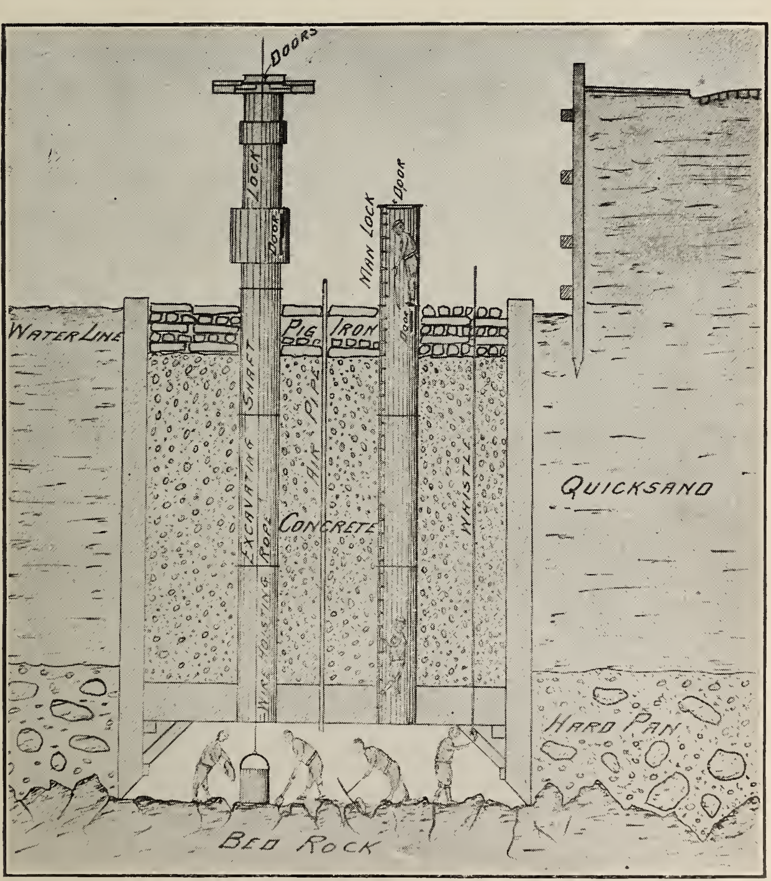
T. Kennard Thomson, '86.

The best foundation for a bridge or building is of course bed rock, and it is almost the only foundation which does not permit of more or less settlement. Where there is no water to contend with, all that is necessary is to "shore" at the sides sufficiently to prevent caving in, while the material above rock is being excavated. But when water is encountered and the rock is not too far down, the material can be excavated by the open cofferdam method, which means driving sheeting down all around the excavation and continually pumping the water out.

The old method was to drive two-inch or three-inch planks ten or twelve feet long. When the excavation was completed to the bottom, a second set was driven inside the first. This was continued to the depth desired, but was in treacherous soil a very poor arrangement and the sides were almost invariably forced into the excavation, making the opening much smaller than desired.

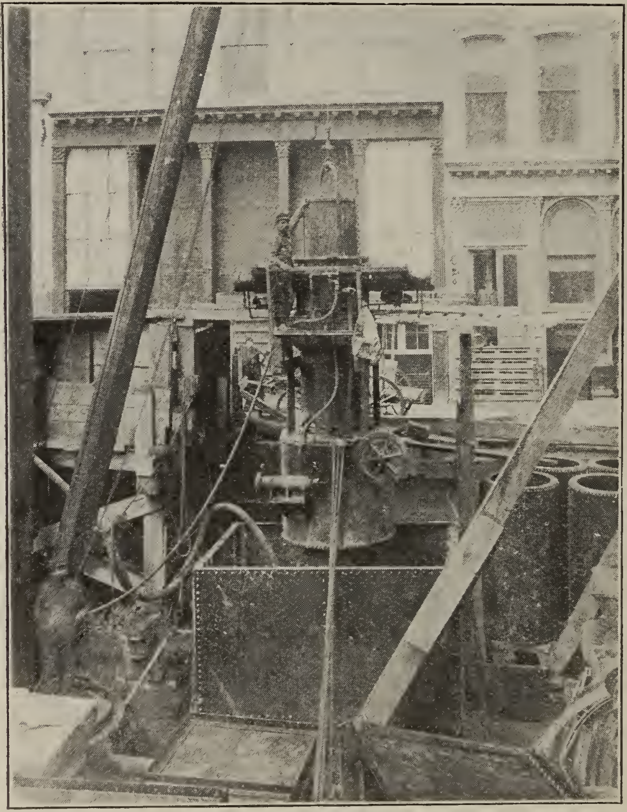
The more modern sheeting consists of timbers up to 12″ wide with two strips nailed on one side and one strip on the other, forming a sort of tongue and groove arrangement. These are driven with a pile driver so that the points reach bed rock. In case the excavation does not go to rock, they are driven two or three feet below the level to which it is intended to excavate. By this means the water can be kept down by pumping, there being very little if any leakage through the sides. The material excavated will be in a tolerably dry state to a depth of about 30 feet below water, which is pretty near the limit in bad material. An attempt to go much below this necessitates an enormous amount of bracing, etc., to keep the sides from collapsing.

It is a question of dollars and cents in each case, whether it is better to use timber sheeting or one of the many forms of steel piling. For bridge work, when the rock is at greater depths; and for buildings in cities, where the rock may be at less depths, it is necessary to use the pneumatic caisson for economy and safety.



A TYPICAL CAISSON.—SOMETIMES THE CAISSON IS CARRIED THROUGH HARD PAN AS SHOWN, BUT MORE OFTEN THE CUTTING EDGE STOPS AT HARD PAN AND THE EXCAVATION ONLY IS CARRIED DOWN

A pneumatic caisson is built in the shape of a box having four sides and a top or roof but no bottom. This box is made the exact size of that part of the pier which is to rest on the rock. In the roof are one or more openings for shafts, generally three feet in diameter, for removing material and allowing men to enter the box or air chamber. On top of the box is placed concrete to form a part of the permanent pier, and at the same time to furnish weight to overcome the friction of the earth on the sides and the air pressure in the air chamber. The amount of air pressure being governed by the depth of water, should be just sufficient to keep the

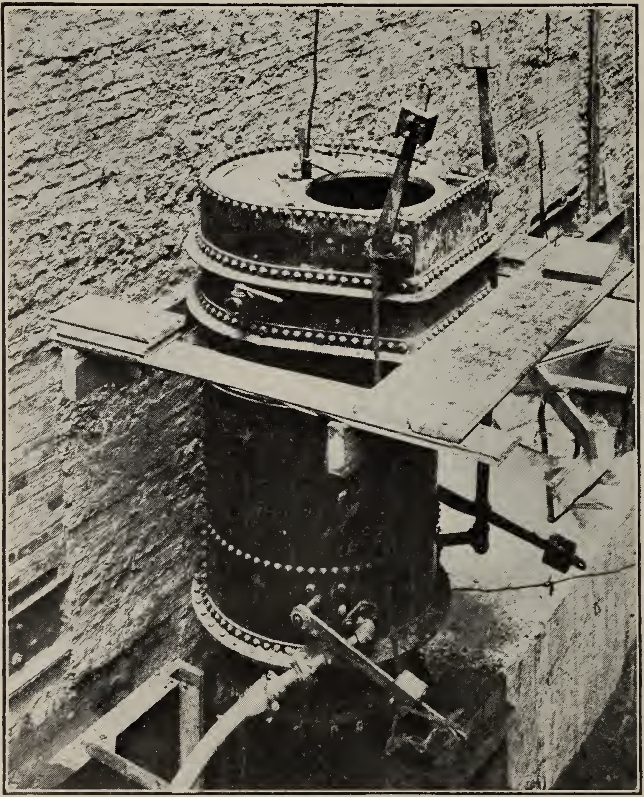


MUTUAL LIFE BUILDING, '00-'01.—BUCKET ENTERING LOCK.

water out of the air chamber. As each cubic foot of water weighs 62½ pounds, the pressure per square foot is 62½ pounds for each vertical foot of water to be resisted, which is equivalent to .434 pounds per square inch. For a depth of 100 feet of water, this is 43½ pounds per square inch above atmosphere, which is about the limit of human endurance. The first pneumatic caissons in this country were used in 1852 for a bridge over the Harlem River, New York City, where a number of cast iron cylinders were sunk to support the piers for a draw bridge. In this case a French expert was engaged at a big fee per diem, to come over and explain the process. The story has it that the contractors quickly learned all he had to teach and let him go after a week or so.

In all the early caissons, the air lock was placed in the air chamber, whereas it is now (except on very small caissons, say 3′ diam.) always placed on top of the shaft above the permanent work. For many years the hoisting apparatus was placed in the lock or shaft so that it was necessary to draw the material up into the lock from the air chamber, to shut the bottom door, and then hoist the material out of the lock. Now, there is a hole or slot in the upper door of the lock which permits the hoisting rope, a wire cable, to remain attached to the bucket during the entire ascent or descent, a very important point when the speed of the work depends on the number of trips the bucket (one-half a cubic yard capacity generally) can make an hour. I have frequently seen the bucket make 20 trips an hour. Wherever possible, it is much cheaper and quicker to "blow" the material out rather than shovel it into buckets to be hoisted out. This is done by means of a 4-or 5-inch iron pipe carried down through the concrete to the deck, where a short flexible pipe with proper valves is attached.

The sand hogs (caisson men) shovel the sand, clay, etc., around the bottom of the flexible pipe; then the valve is opened and the compressed air in the caisson immediately "blows" all the loose material through the pipe and the valve has to be shut while more material is shoveled. Some very rapid excavation has been done this way, especially in some of the East River caissons. It requires about 10 pounds of air pressure in the caisson to blow successfully, and in river work the water is often 20 or more feet deep before the excavation starts. At the top of the blow pipe, it is generally necessary to have an elbow so that material can be discharged into the river or into scows. The force of the sand, small stones, etc., is so terrific that an iron elbow 2 ins. thick is often worn through in a few hours. Especially hard metal is therefore indispensable.



A CAISSON LOCK.

KINDNESS OF LOUIS L. BROWN, '95. THE FOUNDATION COMPANY, N.Y.

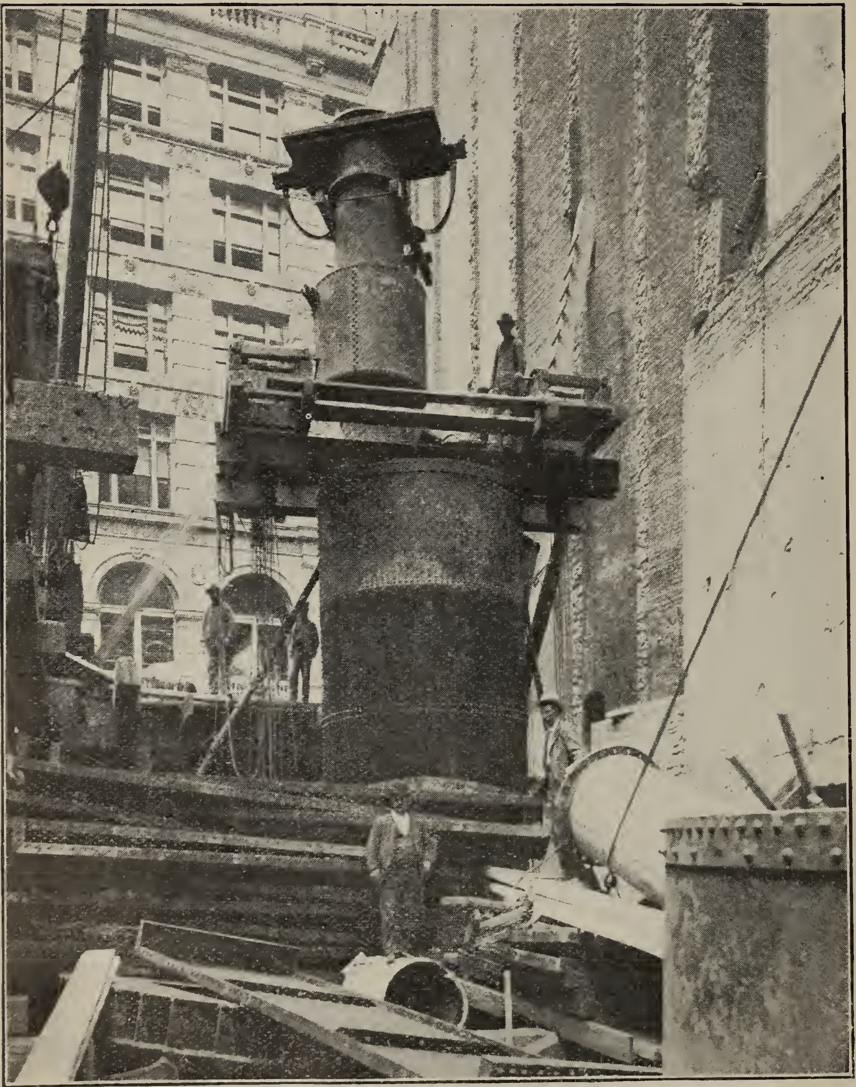
Frequently, especially in city work, the amount of concrete to be placed in the cofferdam on top of the air chamber is not sufficient to overcome the air pressure and the friction, which varies from 50 to 650 pounds per square foot of contact surface. In such a case, the air pressure is reduced a few pounds and sometimes even to a pound or two (where it is safe to do so) for a few seconds, to allow the caisson to sink a foot or two into the excavation already made below the cutting edge. On some jobs, it is entirely too dangerous to reduce the pressure (called "blowing") in this way, and it is very necessary to add more weight, such as pig iron, cast iron blocks, etc., to make the caisson penetrate to the proper depth. Hundreds of tons additional weight are often required.

Caissons were first built of wood—now they are built of wood, steel, or concrete, according to the judgment of the engineer. The Mutual Life caisson is a good example of a steel caisson, and that of the East River Bridge, a recent example of how not to do it in wood.

COFFERDAMS.

In early days it was customary to start stone or brick piers directly on top of the caisson without use of cofferdams. This proved a mistake. In the first place, it did not allow of the weight being adjusted as required, to overcome the resistance, for in that case the masonry always had to be kept above water. I have often seen cases where the top of the concrete in the cofferdam was 20 feet or more below the surface of the water. It is just as dangerous to have a caisson too heavy as to have it too light. In the second place, I have known the friction of the earth, etc., to be sufficient to tear open the joints in the fresh stone or brick masonry. Even with good up-to-date Portland cement concrete, where there are no joints except at the deck, the caisson has been known to separate from the concrete above.

Most caisson men in their early days fall into the error of wanting to make the caisson bigger at the bottom than at the top, thinking to reduce the friction thereby. On the contrary, the reverse is the result, for as a rule the material falls into the space left above the cutting edge, and binds the caisson much more tightly than would



COMMERCIAL CABLE BUILDING.—LOCK BEING LIFTED ON.

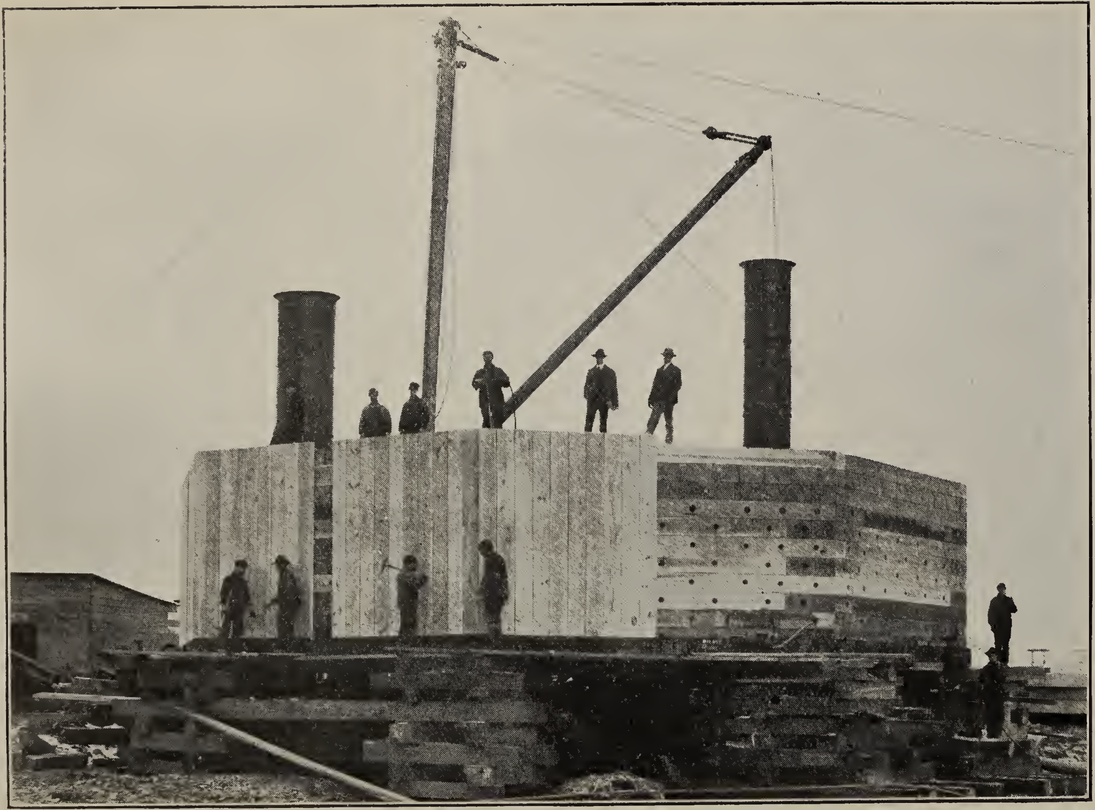
the regular friction. In sinking the Hawkesbury bridge in Australia, however, an unusual thing happened. The surrounding material did not fall against the sides of the cylindrical caissons, so that there was practically no friction. This being so, it was found impossible to guide the caisson to keep it in place and plumb. The contractors stopped sinking, packed new material all around the caisson and let it stand about a year before they started in again. This shows the bad results, both ways, of tapering a caisson.

When the site is covered with water, there are three ways of getting the caisson into position:—

First, to build the caisson on shore and skid it on runways into the water.

Second, to build it on a floating pontoon made of 2 or more sections bolted together. In this way the caisson is usually built with 4 or 5 feet of cofferdam attached. When all is ready, the bolts are taken out of the centre joint of the pontoon, dividing it into two sections. Stone or other weights having been placed near the centre, the water is permitted to enter, allowing the caisson to sink, until it draws about 8 or 10 feet of water. Sometimes in sinking, the extra weight under the centre of the caisson is sufficient to force the pontoon from under the caisson. Struts are sometimes attached to force the pontoon from under, and frequently tugs are used to pull the sections apart. The caisson is ready to be towed into position and to have more cofferdam added before concreting and sinking commences.

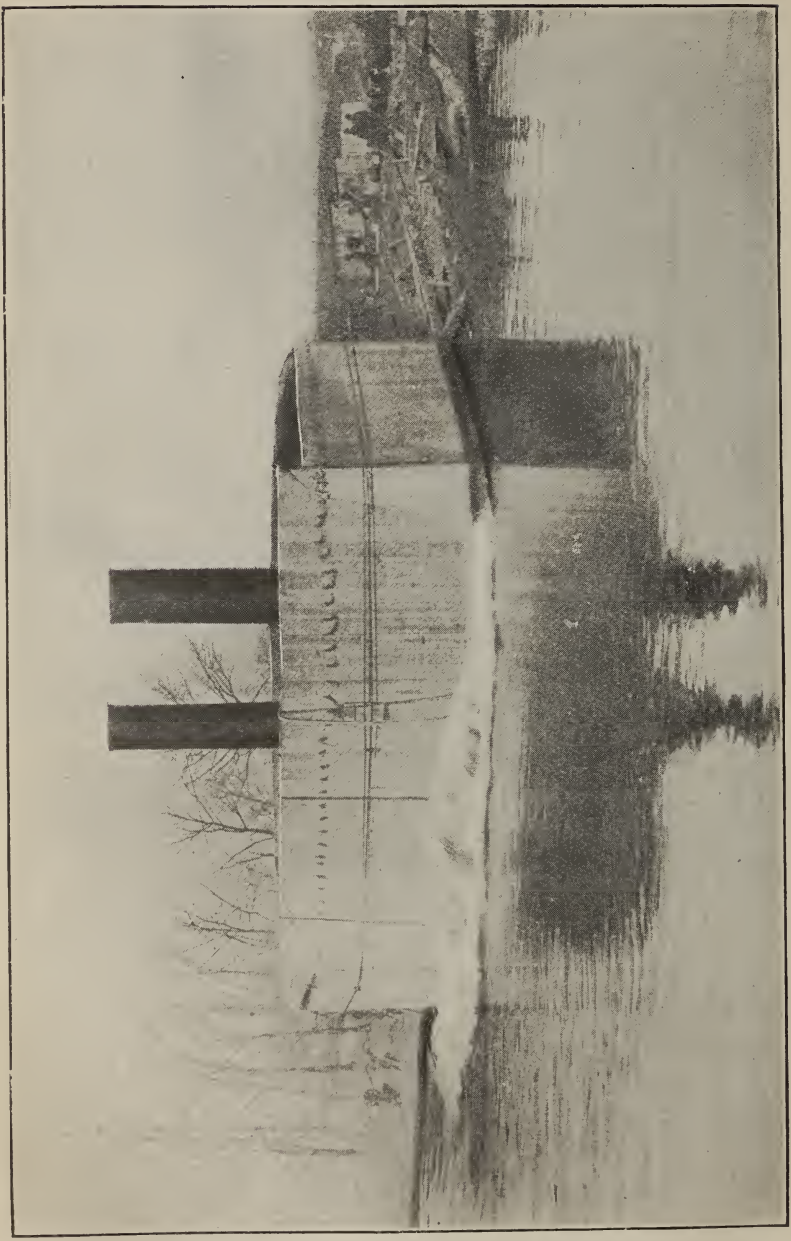
The third method consists of building on a temporary platform and lowering into position by means of screw. It is used where there is not enough water to float the caisson, and where it is not economical to dredge a channel. I might state here that concrete is the only rational material to put on the deck of a caisson. In sinking river caissons, as a rule, there is very little danger of injuring adjoining property, although there are cases where there is danger of undermining an old pier, and care has to be exercised to prevent the caisson being carried away. This indeed actually hap-



CAISSON BEING BUILT ON SHORE.—KINDNESS OF MR. LOUIS L. BROWN.

pened out West, and locomotives were hitched to it to try to hold it. In Nova Scotia, also, an iron caisson was carried to sea in a storm and never found. There is also danger of a caisson turning turtle, especially if not properly designed. A river caisson was once filled with concrete in the air chamber. The railroad officials, however, were afraid of concrete, and they allowed the contractor to put only a few feet of this material on the deck. Before the masonry was started an exceptionally high tide occurred which broke the bond of the concrete with the rock and lifted the whole mass, which had to be dynamited after being towed away. If the men in charge had taken the trouble to calculate the buoyancy, this accident would never have occurred, as 6 inches more concrete would have saved it. In another case the foreman used too big a charge of dynamite and blew the end out of a caisson which was just ready to sink. In one case a very expensively designed caisson was sunk for some water works. A water pipe about 8 feet in diameter was carried up from a tunnel below through the air chamber to the surface and the whole work completed. The air chamber, for economy, had been filled with sand instead of concrete, and when the water pressure against the roof was sufficient to raise the whole caisson, the big water pipe of course gave way.

It is a simple matter to calculate the air pressure, the weight of the materials, etc., but, as we have seen, the failure to do this has resulted in many serious accidents. There have also been many accidents to land caissons, but generally of a different nature. The first caissons to be built under a sky scraper were for the Manhattan Life Building, in 1894, and Mr. Francis H. Kimball, one of New York's best architects, deserves the credit for having the courage and foresight to insist on a rock foundation by means of caissons. Owners and architects were very slow to follow his example, which was considered a freak at the time, but now they are rapidly coming to see the necessity of having a foundation that will not be undermined by an adjacent building or future tunnel—a danger which can be better appreciated when it is known that all of lower New York rests on a bed of quicksand, which flows like water.



LAUNCHING CAISSON, FORDAM HEIGHTS, HARLEM RIVER.—KINDNESS OF MR. L. L. BROWN.

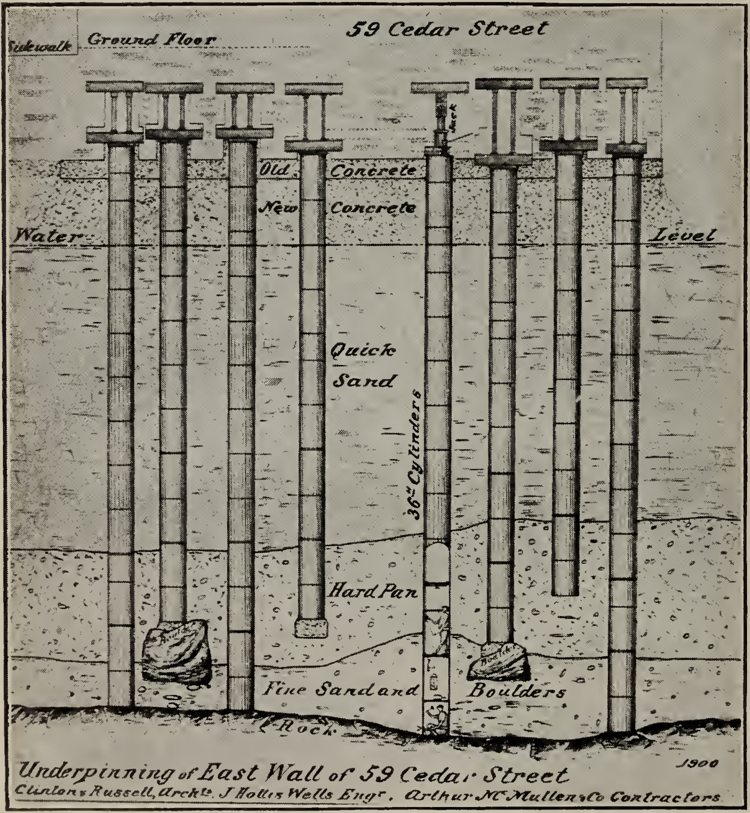
Under the quicksand is found more or less hardpan, some good and some very poor. The bed rock itself, though sometimes decomposed quartz, is generally what we call New York gneiss, fully good enough for any load it will have to carry, which is limited to 12 or 15 tons per square foot, the load allowed on concrete by the New York building laws.

All sorts of liberties have been taken with New York caissons, with very expensive results. For instance, the caisson itself has been made so weak that the sides have collapsed. In a certain caisson which was 8 feet wide originally, a 29-in. bucket could not pass into the air chamber.

The caisson has broken away from the cofferdam above—necessitating tunneling down the rest of the way. An interesting case occurred here where the owners at first wanted their caisson stopped in good hardpan. After passing through 7 feet of hardpan, they decided that they wanted bed rock for their building. When an adjacent caisson was sunk, a tunnel was run to this caisson and the excavation carried down to bed rock 15 feet below. When this was filled with concrete, the other end was successfully undermined and filled up.

In one case a caisson was sunk with a temporary deck or roof. Four feet of concrete had been placed in the air chamber when the temporary weight and roof were removed to allow the column bases to be set. In the meantime, water pressure got busy and lifted the whole caisson bodily. It had to be blown to pieces.

In sinking caissons in the city, there is great danger, unless proper care is taken, of drawing the material from under adjoining structures, and many buildings have been badly cracked and thrown out of plumb 4 or 5 inches. In one case an open cofferdam, not very deep at that, caused an adjoining steel building which was nearly completed, to settle until it was about 16 inches out of plumb. In this case, the terra cotta floors were all taken out, and the building, at great expense, "jacked" back to its original position. In another case, an elevated railroad structure had to be continually "jacked" up as the foundations settled, and the total settlement amounted to much over 12 inches. It is needless to say that most accidents of this sort are due to lack of experience and proper foresight. On one occasion a sub-foreman could not find any heavy timbers with which to "shore" up a caisson which was standing 20 feet high, and in which excavation had just started. Instead of going to the superintendent he used a 3-in. plank for a "shore," with the result that the caisson toppled over and the concrete all had to be broken up.



THREE-FOOT CAISSONS UNDER AN OLD BUILDING.

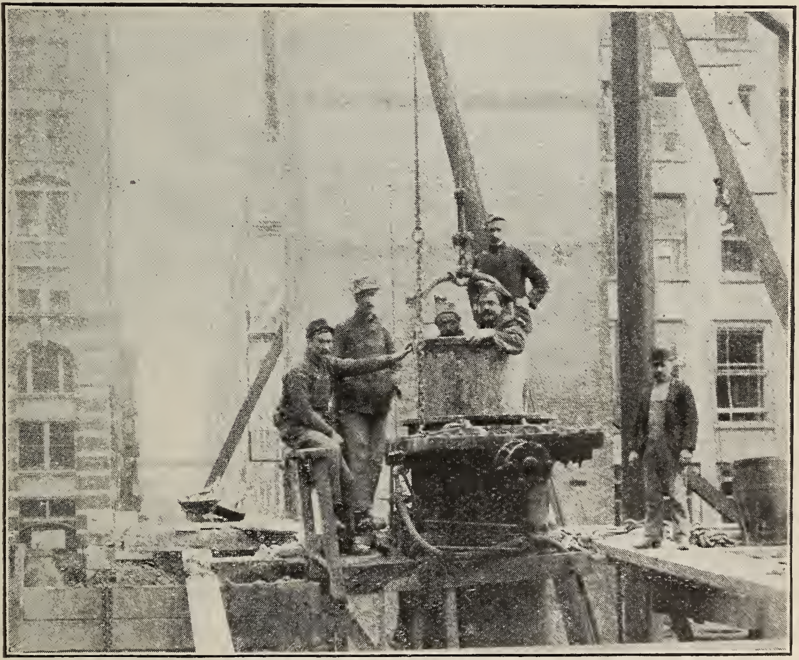
An experienced man can generally tell how close to an adjoining building it is safe to sink a caisson without underpinning or "shoring." When the caissons are not close to the adjoining building, inclined "shores" are used, but if the caisson is very close to a heavy structure, it is necessary to take the weight off the old foundations by the old method of "needles," or by putting very small (say 3-ft. diam.) caissons directly under the building one at a time. This method has been described by me in one of my previous "papers" and in the Engineering News of March 28th, 1901. The method of forcing small pipes, say from 8 to 10 inches in diameter, under a building, has been tried a number of times, but is not reliable and has given trouble by allowing the building to settle after the pipes were all in place. The reason for this is that the pipes were too small to send a man down. Hence there was no way of telling if they were resting on a good bottom. When an adjoining caisson had loosened up the surrounding quicksand and destroyed the friction, the building would force the pipes farther down and would require to be "shored" up some other way. Of course, with a caisson from 27 to 36 inches, inside diameter, it is possible to get a good safe foundation, though at a considerable expense.

Filling the air chamber is a very serious matter, that does not receive as much attention as it deserves. There are two ways of doing this. One is to bench the concrete, starting at the sides and working towards the shaft, and ramming mortar or concrete directly under the roof of the caisson. This of course necessitates a very dry concrete, which requires a great deal more care than is necessary where wet concrete can be used. The other method is to fill the caisson nearly to the deck, take the air off and dump grout and very wet concrete down the shaft. This cannot be done in a very large caisson, and requires great care in a small one, as it is hard to make the concrete wet enough to spread properly down below. It is marvellous where the water goes to in such an operation. I have seen such concrete dumped in a shaft where there was no escape for the water, and where one would expect to find slush in the shaft. Instead, one would find fairly dry concrete. No concrete expert would believe, without seeing it tried, that so much water would be required.

We often hear some one talk of mysterious failures of concrete in the open, or say that he has examined a caisson which has been removed, and found that the concrete had not set up properly under air. After putting in a great many thousands of cubic yards of concrete, both in compresed air and out of it, I am absolutely satisfied that any failure of Portland cement concrete is due, not to the materials, but to the ignorance or carelessness of the men mixing and handling. This of course is under the assumption that a reliable cement is used, and that the materials are up to the specifications. I am satisfied that the so-called mysterious causes would be easily explained if the process were carefully watched. For instance, one frequently sees a contractor transporting wet concrete in a bottom dump bucket from which the water and cement are escaping, leaving the sand and stone in the bucket. As to concrete not setting up in compressed air, I know from many examinations that the concrete in compressed air sets up quicker, and as well as, if not better, than out of it. At least 12 hours should be allowed for setting before the air is taken off, especially where the concrete will have to withstand the pressure of a head of from 50 to 100 feet of water. It has been claimed that concrete can not be made water tight, and we have known of cases where the water has found its way up through a pier 90 feet high. This is probably true of the old fashioned dry concrete, but with care I have made a water tight layer of concrete under air pressure, about a foot above the cutting edge, which was sufficient, after the caisson had been filled, to prevent a head of 85 feet of water from percolating through. The trouble of concrete freezing in a caisson does not exist, provided that it is not frozen before it enters the lock.

Sand hogs, as the men who work in compressed air are called, are probably the poorest paid of all labor unions, considering the amount of work they turn out. The increased amount of oxygen makes them work hard and well as a rule, and gives them good appetites, for one seldom sees a lean sand hog. The work however consumes their energy and there are not many old men among them. They used to get $2.50 for an eight-hour day, that is 7½ hours actual working time, and a half hour in the middle for lunch. Now the union in New York have had this raised to $3.50.

This is for pressure up to about 20 pounds per square inch. Above this the hours decrease and the pay increases as the high limit is approached, which is about 45 pounds per square inch. At the high pressure, men work only about 45 minutes, twice a day, taking three hours' rest between two successive shifts. Even then, with short hours, the results are often fatal. The doctors can of course say that it is dangerous for certain men to go into compressed air—for we know a man must have a good heart and lungs and be in good condition. On the other hand, many who are apparently sound cannot stand the pressure. The first effect generally felt is



A MUTUAL LIFE CAISSON, '00-'01.—SAND HOGS GOING TO WORK.

the pressure on the ear drums especially if one has a cold. The drums are often ruptured, causing intense pain. The next is what we call the "bends." This is supposed to be caused by the compressed air forcing itself into the pores and not escaping when the victim leaves the lock, causing pain and annoyance. Many have more or less severe attacks of the "bends" without serious results, but the next step is paralysis, from which recovery may be possible, or the trouble may last for life or prove fatal on the spot. One man was paralyzed during the last year in only 20 pounds of air, an occurrence hitherto unheard of at such low pressure. A remedy that will cure a man of the "bends" once may have no effect on him another time, as I know to my sorrow.

The purity or foulness of the atmosphere has also much to do with a man being "knocked out." In the Harlem river, which, to the disgrace of New York, is a big sewer, the bottom of which is intensely foul, we have sunk caissons and had much trouble with the bends. The trouble continued until the caissons got down to the hard clean clay, and though the air pressure was then much greater, the men suffered much less.

In winter, when the thermometer is down to zero, the air chamber is comfortably warm, but in summer the compressed air makes the air chamber very hot unless the air pipes, as they frequently are, are passed through tanks of water or ice. It is peculiar that as a rule sand hogs are almost useless on outside work, and even some high-priced superintendents who are very valuable in the caisson, can not earn their salt in the open air.

THE VALUE OF DESCRIPTIVE GEOMETRY IN ENGINEERING PRACTICE.

NORMAN R. GIBSON, B.A.Sc.

It is safe to say that very few undergraduates in Applied Science, who have the subject of Descriptive Geometry on their curriculum, regard it as anything else than a difficult course, placed there as a means of expanding an already well filled time table. This was the prevailing opinion a few years ago and probably it has not changed much since then.

The purpose of this article is to draw attention to the fact that Descriptive Geometry is not an altogether abstruse science, but, if looked at from a common-sense standpoint, is a simple method of solving many problems that occur in practical designing. Its use is essentially adapted to designing, and those who look forward to a rigorous training in the drafting room will do well to consider their Descriptive Geometry carefully, and thereby save themselves much trouble, and provide themselves with a means of overcoming many difficulties.

Speaking generally, any piece of work of such magnitude or complexity as to require a drawing to make possible, or to facilitate, the construction of the work, must be shown in plan and elevation; these, usually, being the horizontal and vertical projections of the structure. If all the lines of the structure lie in either of these two planes, the problem of drafting is one only of simple orthographic projection, but, if any line is inclined to either of these planes, the problem becomes one in Descriptive Geometry. If any line is curved and not wholly in one of the projecting planes, the problem may be somewhat more difficult; and if the structure is represented by a number of curved lines in different planes, the problem may become very complex.

It is readily seen that very often all the lines representing a structure do not lie in the horizontal or in the vertical plane, and hence the variety of applications that may be made of Descriptive Geometry is at once suggested. The most common applications are found in the design of steel pipes, stacks and steel plate work in general, where drawing is made difficult by bends and intersections. In the design of reinforced concrete work, such as flared draft tubes for water-wheels, skewed arches, and complicated forms in general, the methods of Descriptive Geometry are not only useful but essential. One of the simplest problems, but one which often

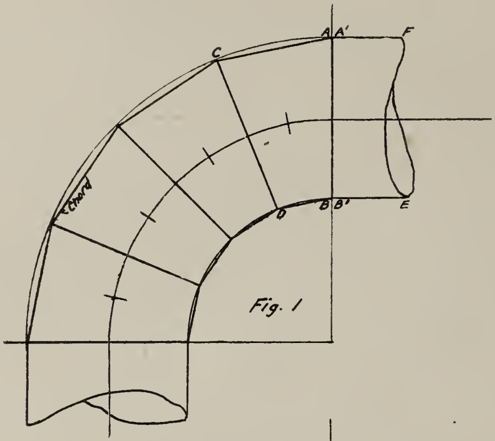


Fig. 1

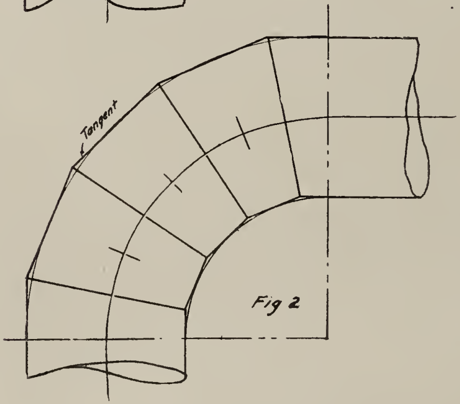


Fig 2

occurs, is to find the true angle between two intersecting lines (e.g., the centre lines of a bent pipe) when given the horizontal and vertical projections of these lines. Another is to develop the plates of an elbow. A third is to determine the angle and size of bent plates for skew connections in structural steelwork.

It is impossible of course in the limits of a paper such as this, to describe in detail any complicated examples of the application of Descriptive Geometry to practical designing; but one case that has come to the writer's notice, and which frequently occurs, will serve to illustrate the point. In designing an elbow for a thick steel pipe of large dimensions, the segments of the bend were laid out as shown in fig. 1, which is apparently the more natural way to do it. A little application of Descriptive Geometry will show that the end A B of the course A B C D is an ellipse, and that the end A′ B′ of the course A′ B′ E F is a circle. The difficulty of fitting these two courses together can only be realized by practical experience. For the case in point, the error was not discovered until the plates were assembled in the field and considerable time and expense were involved in forcing the two courses together. A study of fig. 2 will show the correct method of laying out this elbow. The number of divisions is always twice the number of courses plus two and the segments of the elbow tangents to the curves instead of chords, thus maintaining the correct inside diameter of the pipe.

One word, in conclusion, with regard to the difficulties of Descriptive Geometry. It is safe to say that half the trouble in this subject is due to initial prejudice and the failure to apply some common sense. A little effort of the imagination and a little careful study will overcome most of the difficulties, though it must not be supposed that anything can be accomplished without a fair trial.

It is hoped that in thus drawing attention to the usefulness of Descriptive Geometry, its value will be made more apparent and the subject studied with a better idea of its ultimate worth.

NIAGARA POWER TRANSMISSION.

T. H. Hogg, '07,

During the past summer, the writer was employed by the Niagara, Lockport and Ontario Power Co., on the location of towers, and work incidental to the transmission lines, which are being constructed by that company between Niagara Falls, Ont., and Syracuse, N.Y.

As this line is the longest of its kind north of California, and one of the longest in the world, it will no doubt be of interest to members of the Engineering Society. It is not the intention, in this paper, to attempt to give the technical designs entering into the construction of the line, but simply to give a brief description of the line itself, the country it traverses, and some of the difficulties of its construction.

Power is generated by the Ontario Power Co. at Niagara Falls on the Canadian side, and conveyed across the Niagara River at a point near the Whirlpool, where the gorge is narrow. From there the line is carried on steel towers, placed on a private right-of-way, to Syracuse, N.Y., a distance of 160 miles, and to the other distributing points.

During the erection of the power plant at the falls, contracts for power, with delivery at a certain date, were made with the Syracuse Street Railway. Steel tower erection is of necessity a slow performance, so it became necessary to build a wooden pole line in order to fulfil these contracts. This pole line for most of the distance to Syracuse is placed on the West Shore Railroad right-of-way.

The design of the pole structures will be described later, as they are of a type different from the ordinary. The current carried on these poles is 60,000 volts, three phase. As there is not much of interest in this first line except its length, we will pass it over, and go on to a consideration of the more permanent line which is now being built.

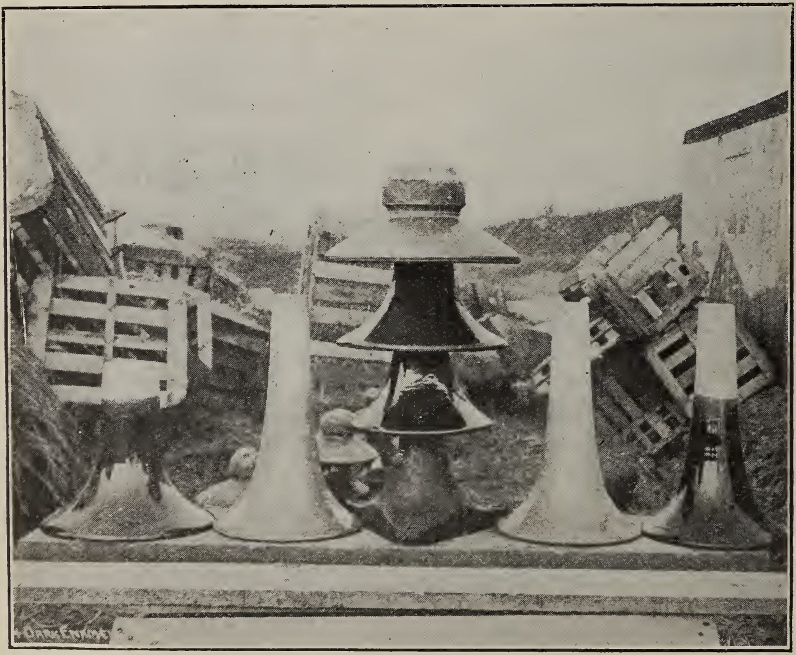
With such a high voltage and its accompanying danger to the public, a private right of way for the location of the carrying structures is absolutely essential. The location of this right-of-way is governed by a number of factors, such as topography, railway and highway crossings, and cost of property. In traversing a section of country so thickly populated as New York State, and of such value agriculturally, this last consideration of cost of right-of-way is a large item. It is of course desirable to approach as near as possible to the larger towns and cities along the route, in order that tap lines to these may be cheaply erected. On the other hand, the more nearly the towns are approached the higher is the value of the land. These elements must be balanced one against the other.

Railway and highway crossings are also a great factor in the location, as it is advisable to have these crossings at right angles, or as nearly so as possible, in order to have ample clearance of the circuits. The topography of the country enters to a less extent into the consideration of location, as, with towers of different heights and spans of different lengths, the engineer has at his disposal a very flexible arrangement with which a very fair grading of the line can be secured, even in rough country.

Angles are avoided as much as possible, because of increased cost, as extra towers are required at such places. Further, angles often occasion weak spots in the line where breaks may occur. Marsh land which extends any distance is also to be avoided, on account of the difficulty of securing good foundations for carrying structures, and also because of the trouble incidental to getting construction material on the ground.

The width of right-of-way varies according to the number of lines to be built. From the transformer station at Niagara Falls to the sub-station at Lockport, a distance of about 18 miles, the width is 300 feet, to accommodate six lines. At Lockport there is a division, right-of-way for three lines being obtained to Buffalo and right-of-way for three lines to Rochester. The width of a branch line right-of-way varies from 10 feet to 50 feet, according to the number of lines, the former being the width for one pole line.

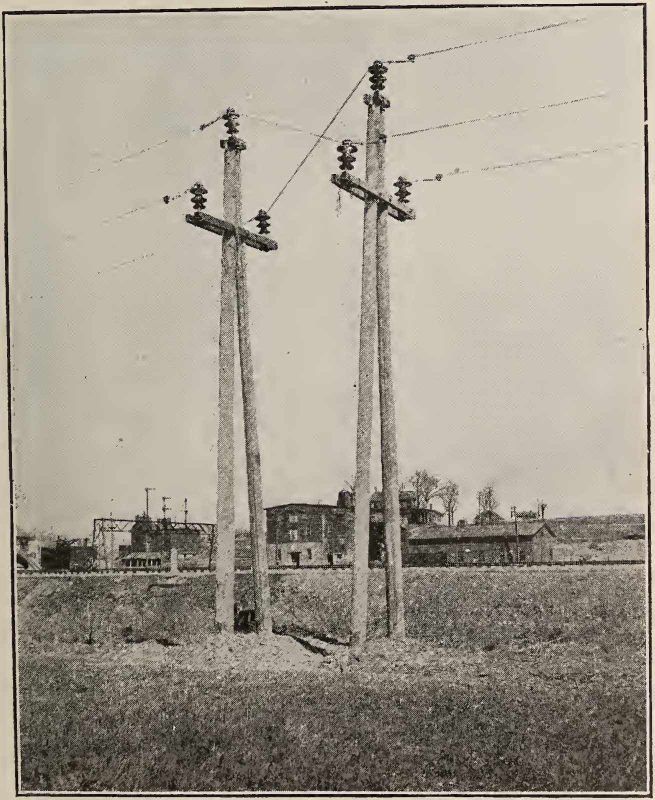
The carrying structures are of several different kinds, and as they are all somewhat novel in this class of work a detailed description of each will be given. The type first used on the Canadian side for low voltage circuits was a single wooden pole with wooden cross-arm, set into the centre of the pole and held firmly with wooden pins. The three-phase current was carried on this, one cable on the top of the pole and one at each end of the cross-arm. It was the intention at first to use this style of structure on the branch lines for heavy voltage work, but it was found that they



INSULATOR FOR 60,000 VOLTS.

were far too light and unstable to carry the relatively heavy loads due to the weight of insulators and cables, and to wind pressure and ice.

Some idea of what this weight is, may be had from the fact that a single insulator and steel pin for 60,000 volts weighs 75 pounds. A number of short experimental lines of these poles were erected, radiating from the Falls sub-station, and these are now being used for the low voltage local transmissions.



"A" FRAME, SHOWING TRANSPOSITION OF CABLES.

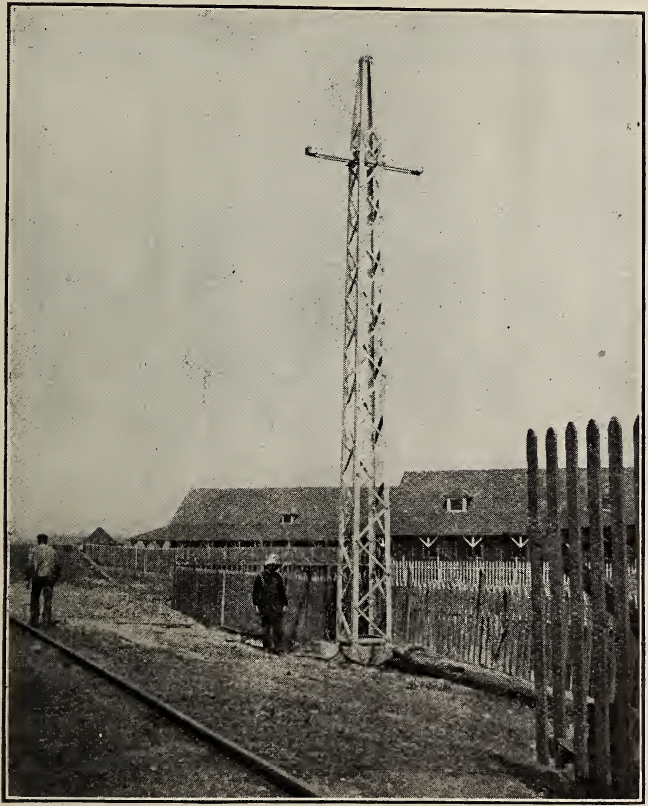
The other carrying structures may be divided into two classes. those used on main lines, and those used on branch lines; but on none of them are there more than the three wires of a circuit. In this will be noticed a difference from the Electrical Development Co.'s main line to Toronto. There each tower carries two circuits. The Canadian Niagara Power Co.'s line from Niagara Falls to Buffalo is similarly constructed. The reason for placing only one circuit on a tower is to obtain as complete an isolation of circuits as possible. A distance of 25 feet is in all cases maintained between circuits. Should any accident happen whereby a tower is injured or destroyed only one circuit will be affected.

The branch line structures are of two kinds,—those known as A-frames, composed of two wooden poles, and latticed steel columns with concrete foundations. Since doubtless but a few of those present have seen the A-frames, a description of them will not be out of order. As the name implies, they are made in the form of the letter A, and consist of two poles with a spread at the base of five feet, where they are tied together with two 2″ x 12″ planks. The cross-arm forms the bar of the figure A, and at each end of the cross-arm is placed one wire of the circuit, the third wire being carried at the apex of the poles. A distance of 7 feet is preserved between wires. These poles vary from 40 to 60 feet in height. The frames are placed at right angles to the line and form a very stiff arrangement.

The maximum span used is 220 feet. The necessities for varying this span will be dealt with later, as will also the reasons for strengthening the line by guys, etc. Heavy cast-iron pins 2⅞″ in diameter are used to carry insulators, which are of the petticoat type, with three petticoats, the top one being 15″ in diameter, and the whole standing 20″ high. The insulator pins are carried on the poles in heavy cast-iron sockets firmly bolted to ends of cross-arms, and to the top of the poles. These insulators, which are used on all the company's high voltage work, come in three sections, and are cemented together and to the insulator pin with neat cement.

The latticed steel columns, which are used on the branch lines to a limited extent, come in standard heights of 31′, 50′ and 60′

respectively. They are made up of four rather heavy angles, and vary from $2\frac{1}{2}'$ to $3\frac{1}{2}'$ square at the base. They are latticed with lighter angles. The cross-arms are riveted to columns at six feet from top, and here the corner angles begin to converge, meeting at the apex to furnish a support for the peak insulator.

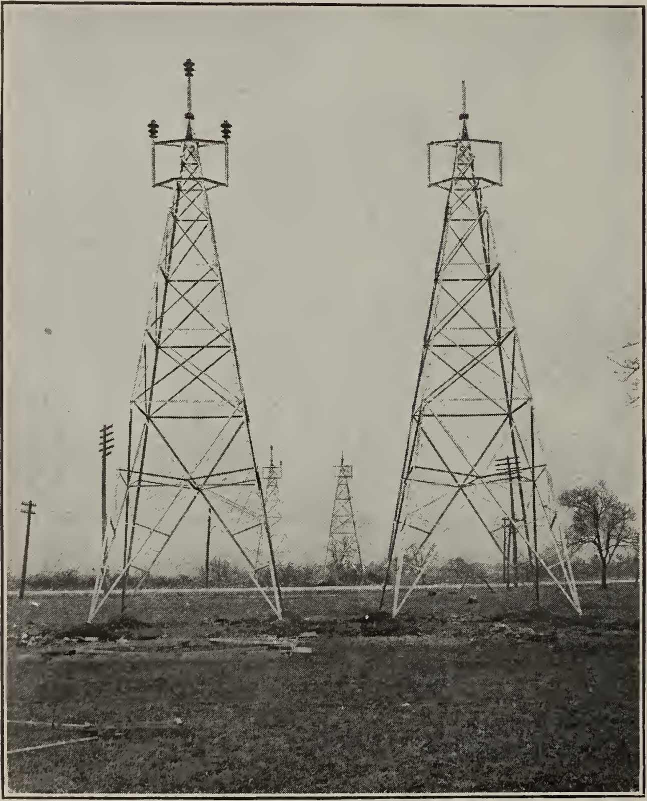


STEEL POLE.

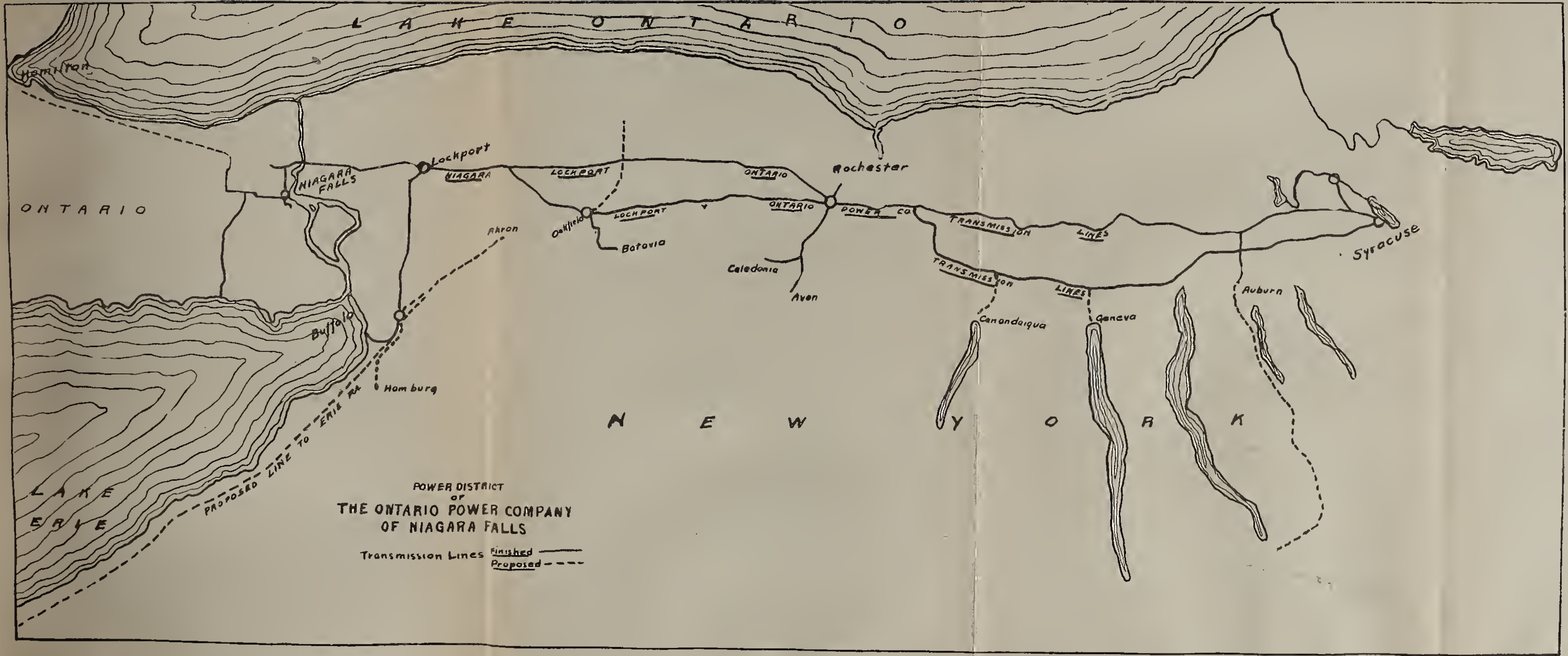
These columns are imbedded in a concrete foundation, 5′ square, and extending 8′ in the ground, with a footing course 5′ x 8′.

The adjacent tangent spans allowed on these towers are 300′, 400′ and 325′ respectively, for the heights, 31′, 50′ and 60′. They are used only where it is necessary to have a stiffer structure than the A frame, with no room for guying, and where a longer span is necessary than can be obtained with A-frame structures.

The main line towers are of two forms. The form first used, but which has now been superseded, is called the Archibald-Brady tower, from the name of the contractors who submitted the design and supplied them. These are of steel, with triangular bases and hollow tubular legs, each leg having a heavy concrete anchorage. Unfortunately these towers have hardly had a fair test, for they were erected during the winter in freezing weather, and the tubular legs were filled with grout, with no provision for allowing moisture



AERMOTOR TOWERS.—BUFFALO LINE.



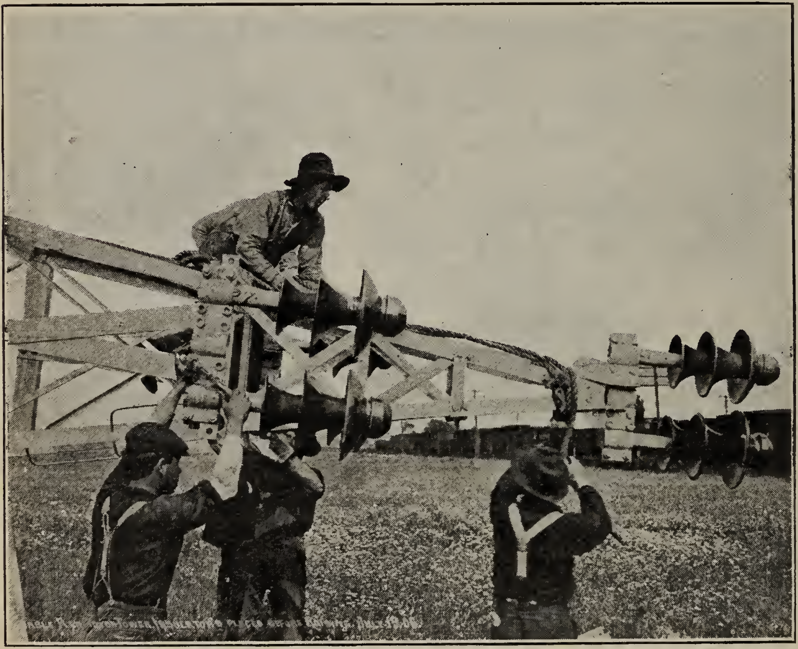
POWER DISTRICT
OF
THE ONTARIO POWER COMPANY
OF NIAGARA FALLS

to escape, consequently the grout froze, and expanding, split the tubes, necessitating a considerable outlay for repairs. However these towers are hardly considered heavy enough for the work, and they are no longer being used.

The style of tower universally used now, is what is known as the Aermotor and is made by the Chicago Aermotor Co. These have square bases, and are made up of angles and light rods, each part being galvanized, thus doing away with the necessity of painting. They come in standard heights of 42′, 49′, 57′ and 75′. The spread of base varies from 15′ to 18′. The foundations for these are of concrete,—mixture 1 : 3 : 5, wedge-shaped to a depth of 5 feet, with a footing course 4′ x 5′. The towers are connected to the foundations by anchor bolts 5′ long, with a heavy washer imbedded in the footing course, the footing being reinforced with expanded metal.

The procedure during construction of foundations and erection of towers is as follows: The centre of the tower is located on the ground, with reference points from 10 to 15′ at right angles to it. The holes for the foundations are then laid out by template, and the anchor bolts located in the same manner. The forms are then placed about the anchor bolts and filled with concrete. After a suitable time has elapsed in order to allow concrete to set, the towers are assembled and erected. The towers are shipped in pieces and are assembled where they are to be erected. All joints and connections are made by bolts, no field rivets being driven. The delicate part of the work comes in the erection. Several methods are used, depending on the nature of the ground and the judgment of the foreman in charge of the work. Where a double line of towers is to be erected, the first line is usually erected with a gin pole, the second line being erected from these, using the towers already placed as gin poles. Extreme care is necessary in raising the towers to a vertical position, as the material used in their construction is rather light.

In all cases where undue strain is likely to occur in a structure, guys are used. These are of 7-16″ steel cable, anchored in the ground with concrete deadmen, and attached to towers at the base of the lower insulators. Where a structure is guyed it is always necessary to use cable clamps, in order to transmit the stress from the carrying cable to the insulator, and thence to the guy; otherwise the stress would be carried into the next span and in all probability the binders fastening the carrying cables to the insulators would be torn off. It is usual to use two or more insulators in place of one, on guyed towers.



SHOWING ATTACHMENT OF GUYS TO TOWERS.

The maximum length of span between carrying structures is 220 ft. for the A-frames, and 550 ft. for steel towers. The reasons for varying the length of spans will be briefly given in the case of the steel towers, and what may be said with reference to them applies equally well to the A-frames.

On a long piece of tangent, with no angles or curves, various things may occur to prevent the use of the regular span, such as creeks, railway and highway crossings, swamps, etc. There will therefore be certain controlling points which can be passed only by a certain arrangement of towers. For example, in the case of a creek crossed diagonally, it would probably be necessary to place the towers at equal distances from the shore on firm ground, not exceeding the allowable span.

These controlling points being located, the intervening spaces may be divided into equal lengths of maximum span. This constitutes the preliminary lay-out and is of course subject to slight changes, as certain of the towers thus located may, on examination of the line, be found to fall on ground unsuitable for foundations, so that by shifting the location a few feet either way, good foundation may be secured.

On rough ground it is also nêcessary to arrange towers so as to secure a fair grading of the line, and yet to keep the spans as nearly equal as possible so that the loads on the towers may be nearly equalized. This consideration of grading the line is materially aided by the fact that there are varying heights of towers.

A standard arrangement of towers is used at railway crossings. Guyed towers are erected as close to the railroad right-of-way as possible. The guys lead away from the railway, thus forming a tight span with small amount of cable sag over the tracks. The next adjacent spans on each side of this tight span are of a maximum length of 150 ft., and guys are so arranged as to make these spans slack. The succeeding spans are of standard length. This arrangement necessitates that the towers adjacent to railroad shall only carry the single span over the tracks, and that stresses which may occur in the tangent will be taken up in the slack span, without affecting the towers carrying the tight span. At important highway crossings it is usual to shorten the span to about two-thirds of the maximum, so that with the ordinary height of towers the carrying circuits may have ample clearance above telephone and despatch lines.

Where a change of direction of tangent occurs, it is made by turning the angle abruptly or by a curve. Two methods are used for turning the angle abruptly,—by turning on two towers and by turning on three. In the first method, the towers are placed at equal distances from the intersection of the tangents. This distance is never more than 30 ft., thus making a span of slightly less than 60 ft. between towers and giving ample room for the two sets of tower foundations. The adjacent towers on each tangent are placed at distances of 150 ft. The angle towers are guyed towards the intersection of the tangents, while the next adjacent towers are guyed both ways. This arrangement relieves the angle towers of any stress which may occur in the tangents and leaves a short slack angle span.

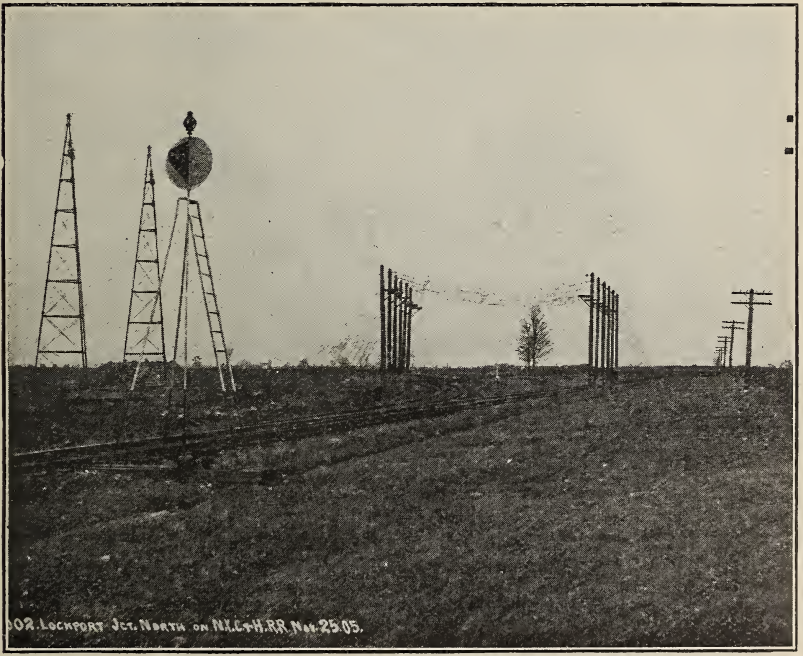
The second method is a modification of this,—by turning on three towers. It is used for sharper angles than the preceding arrangement. Towers are placed 90 ft. distant from the intersection point on each tangent, and these are guyed towards the intersection. The third tower is placed midway between these towers in such a way that the deflection at it is a third of the whole angle. The next adjacent spans on the tangents are of standard length, and the towers are again guyed towards the intersection. This arrangement is more clumsy in appearance and can hardly be considered as satisfactory as the first method.

When it is necessary to turn an angle with a curve (and the reasons for this will be given later), a schedule of allowable spans with maximum deflection angles is used, and these must not be exceeded in the lay out. The allowable span for a certain curve being found from the table, the deflection angles for chords of this length are calculated and the curve laid out on the ground, the reference points for the tower foundations being placed on the radial lines of the curve.

The last tower on each tangent is guyed towards the intersection.

Protective structures are used at telephone crossings, and often also at railroad crossings where required by the railway companies. These are usually made up of a double line of poles strongly guyed and covered with a network of cables, which form a cradle to catch any carrying circuit which may become broken or detached at the crossing.

This network is well grounded. Different protective devices are also used on the towers themselves. These devices prevent a broken live cable from coming in contact with the tower and afford a ground for the current. The dangers ever present with such high voltage transmission are just beginning to be appreciated now, and the requirements for more and better protection at all highways, railroads and public crossings, are becoming far more rigid than they were a year or so ago.



PROTECTION STRUCTURE AT RAILWAY CROSSING.

A clearance of circuits above ground of 25 ft. is maintained. This is increased to 30 feet at important highway crossings, and at railroad crossings; at telephone crossings 12 feet is preserved between circuits and telephone lines. When running parallel to dispatch wires for any considerable distance, to offset the induction which is set up in these lines, it is usual to transpose the carrying circuits every five miles, rotating them through 120°. This rotation sets up contrary induced currents which counterbalance each other.

A table of allowable sags for different spans is used in stringing the cable. This table gives for different temperatures the vertical sags with which the cable must be strung so that with wind and ice at 40° F., the elastic limit shall not be exceeded. The cable used on all main lines high voltage work is aluminum, 642,800 C.M., 0.505 sq. in. area, 0.925″ extreme diameter, and containing 19 wires. The elastic limit is 12,500 lbs. per sq. in., the modulus of elasticity being 9,000,000, and the co-efficient of expansion 0.0000128 per degree F. The computations are made assuming as lowest temperature, 40° F., with $\frac{1}{2}$″ of ice all around the cable, and a wind

SPLICE IN CABLE BEING MADE.

pressure on the rounded surface of the ice covered cable at 15 lbs. per sq. ft. of section. The weight of aluminum is 0.588 lbs., and that of ice, 0.889 lbs. per ft. of cable.

Splices in the cable are made by means of a flexible aluminum sheath about 2.5 ft. long, which just holds the two ends of the cable at once. After placing the ends of the cable in this sheath, they are given five complete turns and this forms the joint. No heating is done during the operation.

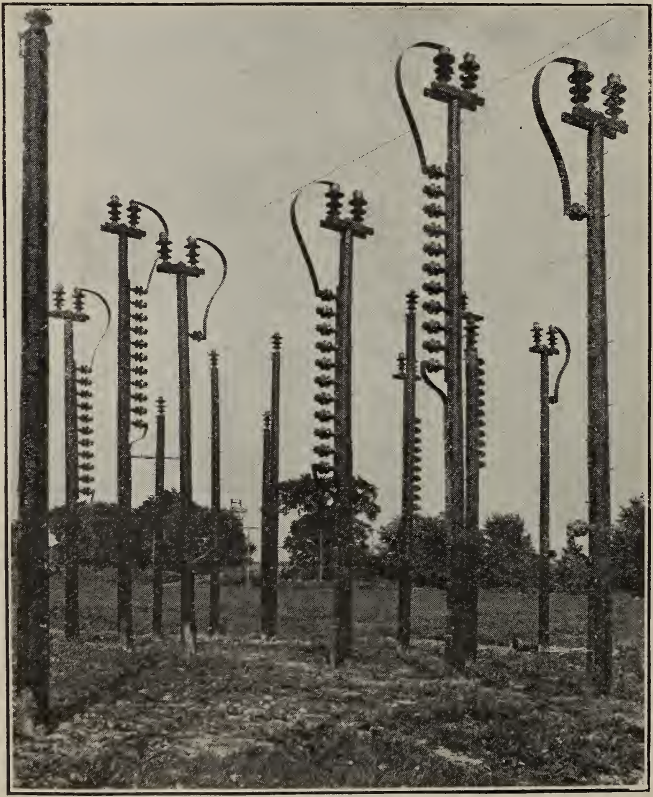
Reinforced concrete poles have been much used of late for transmission work at Niagara Falls, by the other companies operating there, and the question might well be asked why this company have not seen fit to use them. The poles so far used have given very good results, being strong and compact, and permitting of easy erecting and cable stringing. They have, however, one serious disadvantage, which prohibited their use on the work for this company, and that disadvantage is the danger of breakage in erection and the consequent delay in constructing others. These poles are built on the ground where they are to be used, and after being made should be allowed to set at least two weeks before erection. Because of this each broken pole would occasion a serious delay.

Where the right-of-way passes through wooded country, it is necessary to buy the timber rights on each side of the line to a distance of about 150 ft., in order that trees may not be blown over on the cables or carrying structures.

Sub-stations, equipped with step-down transformers, are located at all distributing points and terminals. These stations are all protected with lightning arresters and are of conventional design, so that there is no need of describing them.

It is of course necessary to patrol the line daily when it is in operation, to remedy any small trouble before it becomes serious and to make repairs (such as replacing insulators) where necessary. A patrol road is therefore built on the right-of-way between the lines of towers. This is graded and ditched and kept in good shape for driving over. In some places the building of this road occasioned much trouble on account of the unstable nature of the ground. It was found necessary to corduroy it first and then cover with a couple of feet of earth.

A private telephone line connects the patrol stations which are placed about every twenty miles along the line. These patrol stations are comfortable little cottages of two stories, the lower floor being a store room for supplies for the line, while the upper floor contains the telephones and the living rooms for the patrolmen. There are telephone connections with the sub-stations by the private line and also by the Bell Telephone Co.'s System; so that if a break



LIGHTNING ARRESTERS.

occurs on the private line, the other is available. Three patrolmen are stationed at each patrol house, one always being there, while the other two are on the line.

Disconnecting switches are placed near these patrol stations, so that any section of the line may be cut out while repairs are being made.

The company has just finished the erection of the duplicate line to Syracuse, and a double line to Buffalo. It is the intention in the spring to proceed with a line to Dunkirk and Erie, Pa., with many short branch lines proposed and under way.

For the opportunity of becoming familiar with the work and for the many valuable suggestions received, the writer desires to express his thanks to the Resident Engineer, C. T. Rhodes, and to the Superintendent, W. S. Skinner.

A STEAM TURBINE POWER HOUSE.

C. L. Vickery, '06.

A few years ago the Brooklyn Rapid Transit, in order to meet their increase in traffic, began building the 3rd Avenue Power Station. This increase in traffic was due to a rapid growth of the population of Brooklyn. The suburban movement around New York has increased rapidly of late years, as the facilities for travel to and from New York have been improved. The opening of the new Williamsburg Bridge a little over a year ago greatly augmented this movement. At the same time, it gave the Brooklyn Rapid Transit a second entrance into New York. Another factor to be considered by this street railroad was the probable increase in the Coney Island traffic during the summer months.

Hence, even before their 3rd Avenue Power Station had been completed, the Brooklyn Rapid Transit saw that its output would be insufficient to supply the increased demand. They then began a little over three years ago to consider the project of a power station of greater capacity than any that had been before attempted. This station is now known as the new Williamsburg Power Station. When fully completed, it is expected to be able to supply the increased demand for some time to come.

The company owned a piece of land beside their old Eastern Power House, at the corner of Kent Avenue and Division Street, Brooklyn. This land had a frontage of 200 feet on Kent Avenue and a depth of 340 feet. The rear bordered on the East River. This property was considered admirably suited for power plant purposes. Hence the problem before their engineers was to develop the greatest amount of power in this limited space. This required a careful examination of the various types of prime movers on the market as to their relative adaptability to come within the requirements.

After considering carefully these various types, in regard to economy in steam consumption and general running expenses, their engineers concluded that the steam turbine would be the most suitable. When this decision was arrived at, no turbine of large size had been built. Hence this decision of their engineers was all the more remarkable, and showed great confidence in the future of steam turbines, and in the ability of their makers to fulfil any desired

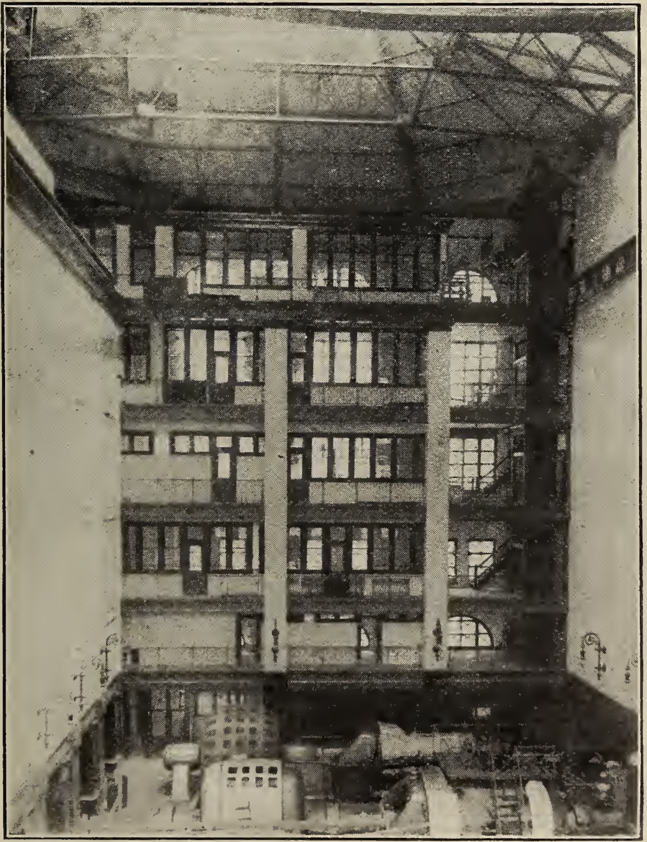


FIG. 1.—OFFICES, ETC.

requirements. The steam turbine had also the decided advantage of developing more power per square foot of floor space than any other type of engine. The first plans prepared called for 10 units, each 5,500 K.W. rated capacity, and capable of a 50 per cent. overload. But after ordering one unit of this size, it was decided to install in the remainder of the power house eight turbines of 7,500 K.W. each, rated capacity. Those with a 50 per cent. overload would make the total output of the station 100,000 K.W.

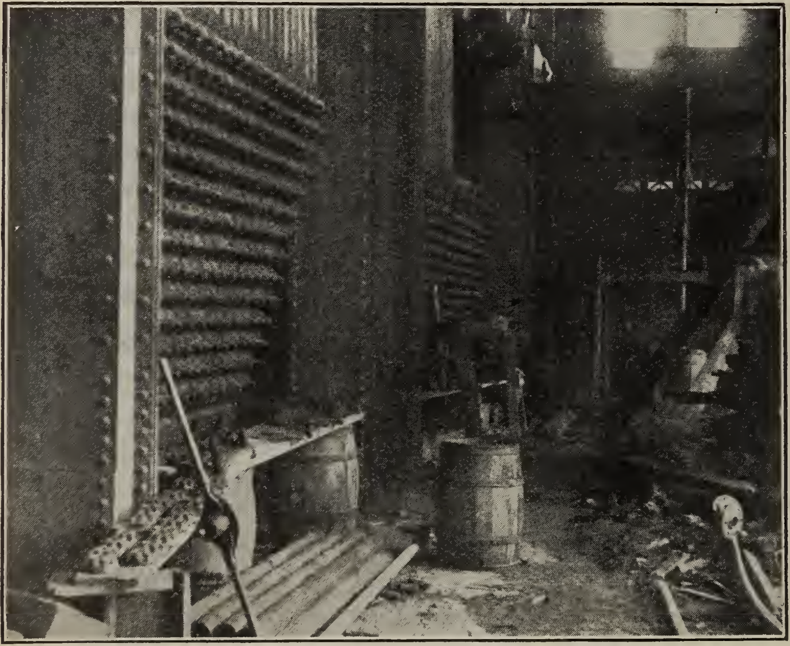


FIG. 3.—REAR VIEW OF BOILERS IN COURSE OF ERECTION.

The station so far completed consists of two boiler rooms, one above the other, each being 140 feet x 120 feet x 38 feet high. Below these is a basement 18 feet high in which are placed the boiler feed pumps, storage tank, heaters, ashpits, etc. Above the upper boiler room are large coal pockets. The turbine room is 140 feet x 60 feet x 60 feet high, each turbine occuping a floor space about 15 feet x 40 feet. Below is a basement 18 feet high, where the condensing outfits are located. This room is equipped with a 50-ton crane, built by the Shaw Electric Crane Co., Muskegon, Mich. The heaviest casting to be handled after erection is the rotor, which weighs 46 tons. A commendable feature of the building is that plenty of room has been left for offices, testing rooms, wash rooms, etc. These are clearly shown in Fig. 1. At the north end of the building, which is to the left in Fig. 1, is the exciter room, 18 feet x 140 feet. Above it are galleries for the A. C. switch-board, the oil-switches, storage batteries, etc.

To produce sufficient steam for this amount of power, viz., 100,000 K.W., it was found necessary to have two decks of boilers one above the other, with 36 boilers on each floor. These boilers are of the Babcock and Wilcox Water Tube type, rated at 650 H.P. each, with a heating surface of 6,037 square feet, made up of 21 sections of 4-inch tubes, with 14 tubes in each section, and 3 drums, each 42 inches in diameter, 22 feet 2 1-4 inches long. The tubes themselves are 18 feet long. The grate area provided is 120 square feet, with a flue opening at the back of the boiler of 31 1-2 square feet. These boilers are built to carry a pressure of 225 lbs. with 100° F. superheat. The steam is superheated by being passed through U-shaped coils, located beneath the drums and above the upper row of tubes. The superheating area for each boiler is 308 square feet. It will be noticed that these boilers are suspended from the girders above, giving free expansion. Fig. 3 gives a back view.

At present there are only 36 boilers erected. These are arranged in 6 rows of 3 batteries each, 3 rows being on each floor. Fig. 4 shows one of these rows. Each battery consists of two 650 H.P. boilers. The superheated steam from each row is collected in a steam main running above the boilers at the back end. The steam main increases from 8 in. in diameter at the first boiler to 14 in. in diameter at the sixth boiler, where it then connects into a 14-in. vertical header. These vertical headers are cross connected to one another by the tie-pipes or equalizing pipes. The down-takes to the turbines are connected to these pipes at convenient points.

This makes a very simple and flexible arrangement and does away with the necessity of a relay pipe line. Each row of boilers may be considered as a unit which, by proper handling of the valves, may be used to supply steam to any particular turbine or to the general system. Also one or more boilers can be cut out in each row, for cleaning, without disturbing the general steam supply, since each boiler-header is fitted with a non-return valve, where it enters the steam main, besides the regular valves.

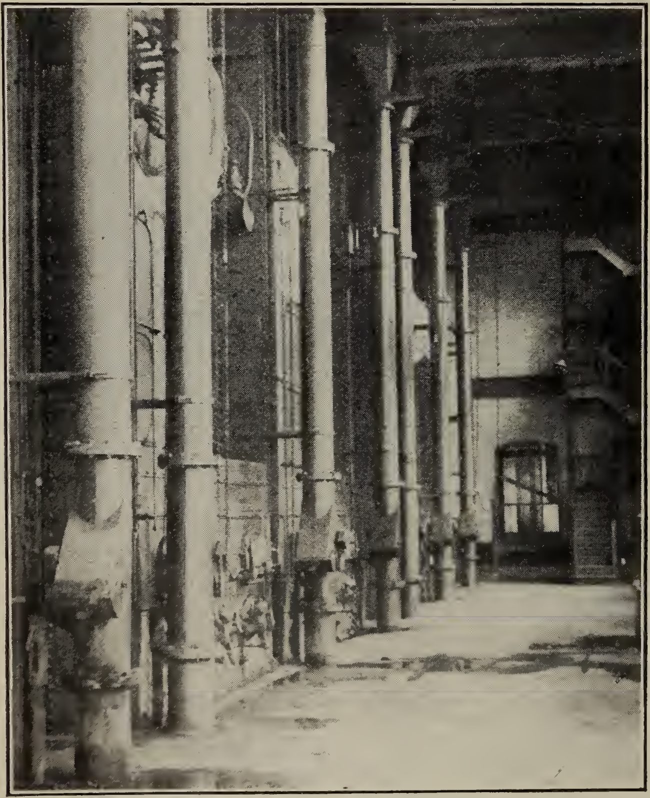


FIG. 4—A ROW OF BOILERS.

A somewhat similar method is followed in collecting the saturated steam for the auxiliaries. The main header is 6 in. in diameter with a 2 1-4 in. pipe leading into it from each boiler. In all the steam lines there are no gaskets, the ground Vanstone joint being used entirely. All piping is extra heavy. At all points where condensation may collect, separators and traps are installed, the water from these being returned to the open heater.

Though a good system of steam distribution is essential to a modern power station, it is even more important to have a never failing supply of feed water for every boiler. Special attention has been paid to this fact as will be shown. The feed pumps, which are 3 in number, and of the Blake compound plunger type, may draw their water either from the open heater, or from the storage tank, or direct from the city mains. The water on leaving the pumps may pass either through the closed heater or by two other separate routes to the main feed lines, 8 in. in diameter, which run parallel with the boilers. These main feed lines are all connected at both ends, forming closed loops. This makes it possible to feed into either end of the main, and also to cut out sections of either line for repairs. Again at each battery a 3 1-2 in. pipe leads from the feed line up over the two boilers and down into the feed line again. This line has a 2-in. branch running to each drum and a valve between the two boilers. Hence it is possible to feed a boiler from either side. This arrangement of piping makes it very easy to get water to any desired boiler.

The grate surface, with an area of 120 square feet, consists of an 18-in. dead plate in front, and two rows of dumping grates each 3 ft. 9 in. deep. On account of No. 3 Buckwheat anthracite coal being used here, in accordance with the city by-law, which prohibits the use of soft coal, it was necessary to resort to hand firing. This is not as objectionable as might appear, since labor is comparatively cheap.

This coal is all conveyed to the station by water. A large coal hoist has been erected capable of handling 240 tons an hour. This hoist is built entirely of steel with galvanized siding. Fig. 5 shows the framework. The coal is carried to the top of the hoist by an endless chain of buckets, and dumped into cable cars, which carry it over and deposit it in very large coal pockets above the upper deck of boilers. These pockets will hold a whole month's supply. From the pockets, chutes run down to each boiler.

The same hoist is used in the disposal of the ash. Small cars convey the ashes from the ash pits below the boilers out to a hopper at the foot of the hoist. From this hopper the ashes are elevated to pockets 20 feet above the tracks. They can then be loaded either on the company's flat cars or on river barges. A small Blake pump 7 1-2 x 7 1-2 x 6 in the basement is used for slushing down the ash pits.

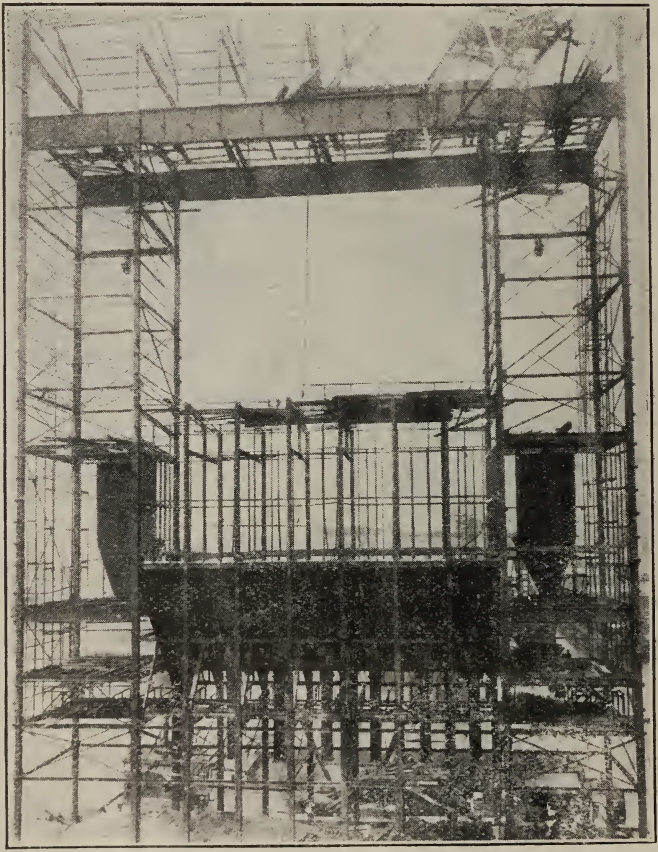


FIG. 5.—COAL HOIST, CAPACITY, 240 TONS.

The draft system was installed by B. F. Sturtevant, Boston. Beneath each row of boilers and between the ash pockets and the front of the boilers, is an air-flue with sectional area 24 square feet. At each end of this flue is a fan driven by a small compound engine 6 1-2 in. and 11 in. by 6-in. stroke. At peak load these engines run at 330 R.P.M., producing a draft behind the grate bars of 5-8. oz. or 1 inch of water.

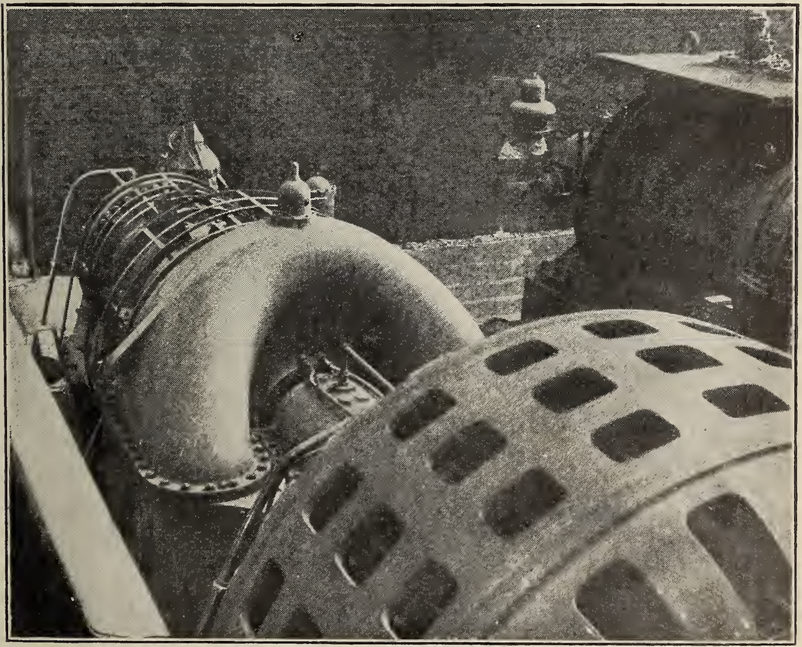


FIG. 7.—TOP VIEW OF ALLIS-CHALMERS TURBINE BEFORE LAGGING.

As the rows of boilers are placed back to back a common flue is built for every two rows with a cross-sectional area of 68 square feet. One flue on the first floor and the corresponding flue on the second floor, discharge their waste gases into a common chimney. This chimney, which is 20 feet in diameter outside, is made of steel lined with fire-brick for a distance of 50 feet, and with ordinary hard brick from there to the top. The chimney stands 210 feet above the grates of the second deck of boilers. When completed the station will have three such chimneys. At present only two have been erected.

Turning our attention now to the turbine room, there has not been as rapid progress in erection as in the boiler house. The first machine to furnish power was an Allis-Chalmers turbine of the Parsons type, rated at 5,500 K.W. A top view of this machine is shown in Fig. 7. This machine has given excellent service since the date it was first under load, March 27, 1906, being out of service only five days since that date. This turbine is of far more than passing interest, as it was the first turbine that the Allis-Chalmers Co. had built. It had never run under load until put into actual commercial service in this station on the above date, when, on an hour's notice, it carried 4,000 K.W. for the whole afternoon. Many interesting articles have been written on the operation of this turbine, which may be found in the engineering journals of May and June of last year. Its excellent performance has thus clearly demonstrated that it can compete with any machine on the market. During rush hours it has carried loads of 9,000 K.W. (a 64% overload) for hours at a time, with momentary swings to 10,000 K.W. While a complete description of this machine would be very interesting and instructive, this paper deals with the power plant in general, and we cannot therefore go into the details. Figure 9 shows the steam end during erection. This shows the regulating device very clearly.

The turbine is direct-connected to a 3-phase Allis-Chalmers Alternator, built at their Bullock works. Figure 10 shows an end view of the Alternator and outboard bearing during erection. This Alternator has a revolving field making 750 R.P.M., and generating current at 6,600 volts. A remarkable feature of this Alternator is its low temperature rise, it showing only 25° C rise after a 24-hour run with a load of 6,000 K.W.

The next machine to get in operation was a Westinghouse-Parsons Turbine. This machine, partly shown in fig. 7, is rated at 7,500

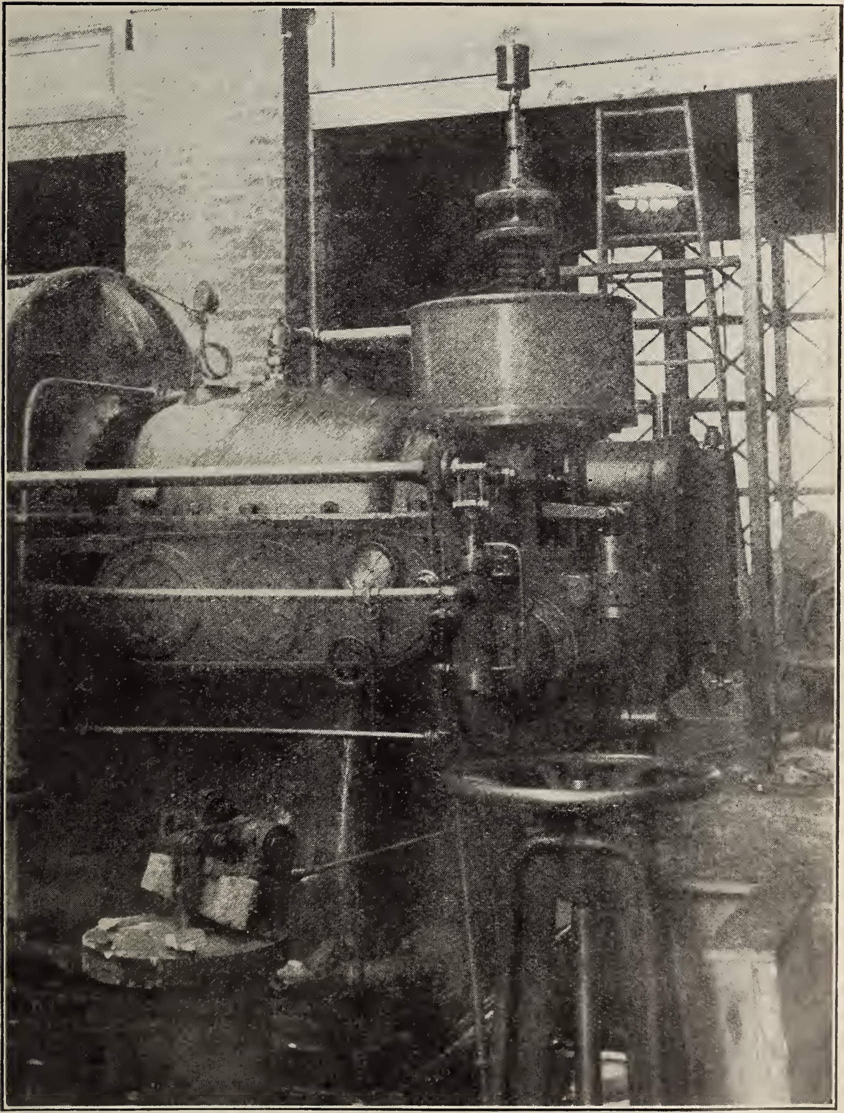


FIG. 9.—STEAM END OF ALLIS-CHALMERS TURBINE, SHOWING REGULATOR, THROTTLE VALVE, AUTOMATIC VALVE AND HIGH PRESSURE BEARING.

K.W., and carries during rush hours 11,000 K.W., an overload of nearly 50%. It is direct-connected to a 3-phase Westinghouse Alternator, with revolving field, giving current at 6,600 volts. Figure 11 shows a Westinghouse stationary armature, without the rotor in position.

At present each turbine has its own oil system, the oil being forced into the bearings by a pump driven direct from the spindle shaft. A gravity oil system has been installed, but is not in working order yet.

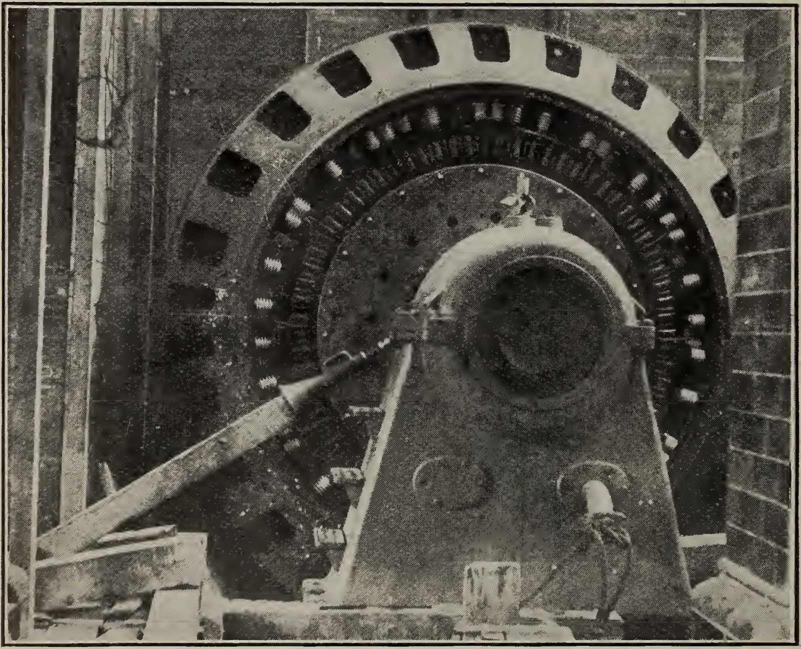


FIG. 10.—END VIEW, ALLIS-CHALMERS ALTERNATOR AND OUTBOARD BEARING DURING ERECTION.

These are the only two machines in operation at present, but work is being rushed on the other units, and another Westinghouse machine is expected soon to be in operation for the winter traffic. Figure 12 shows the two machines now in operation, and the bed-plate for the third. Fig. 14 shows a Westinghouse rotor, also the lower half of the cylinder.

As the economy of a turbine increases rapidly for every inch of vacuum over 26 inches of mercury, the condensing outfits installed deserve mention. Both turbines have the same type of condensing outfit. It is only necessary to describe one of these.

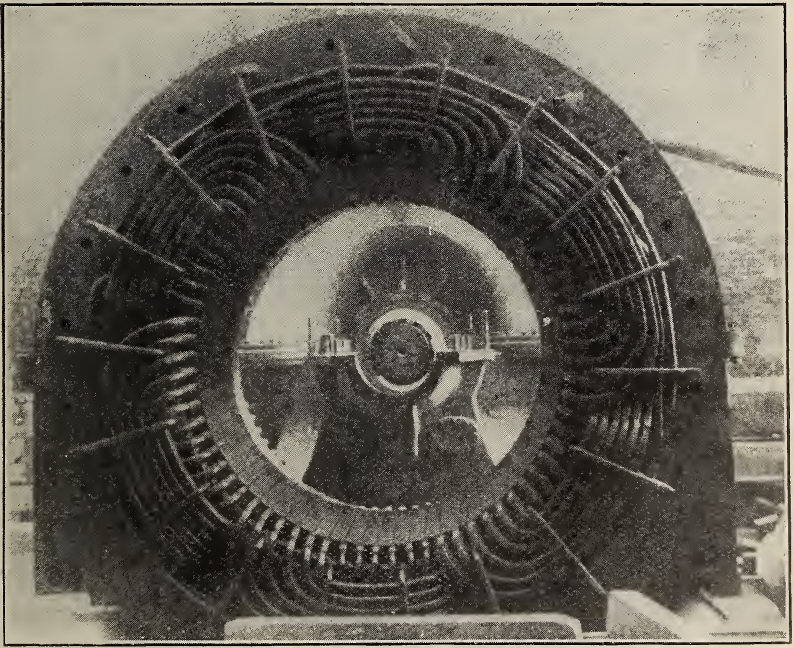


FIG. 11.—WESTINGHOUSE STATOR WOUND AND COMPLETED, READY TO RECEIVE THE ROTOR.

Since the steam in a turbine never comes in contact with any oil, the condensed steam may be returned as feed water direct to the boilers. Again as there was an abundance of cooling water close at hand, surface condensers were considered more suitable. Hence, the exhaust end of each turbine is connected by a suitable expansion joint to a Worthington surface condenser of the counter-current type, with 3 passes of water. The cooling water is forced

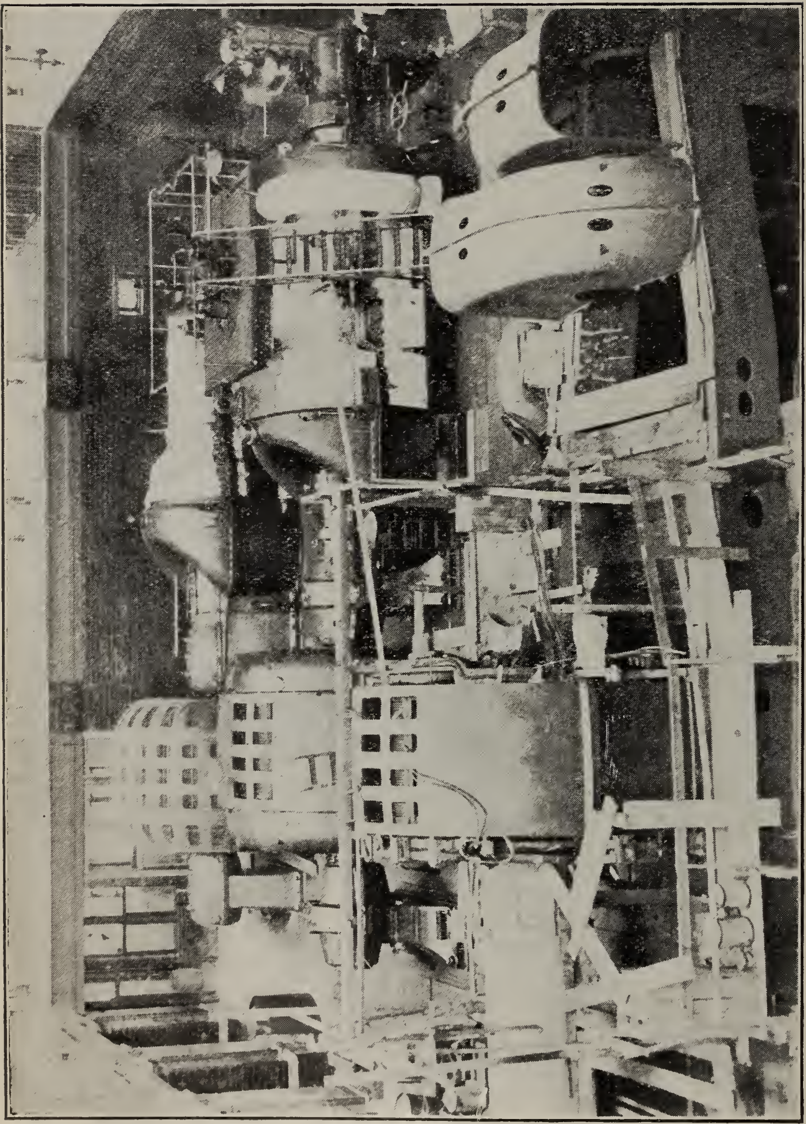


FIG. 12.—ALLIS-CHALMERS TURBINE AND WESTINGHOUSE TURBINE.

through the condenser by a 30-in. centrifugal pump, driven by a Reeves Compound Engine. The cooling surface of the condenser for the Allis-Chalmers turbine is 22,000 square feet, and for the Westinghouse turbine 25,000 square feet. These cooling surfaces consist of brass tubes 1 in. in diameter and 16 feet long. The condensed water is drawn off by a two-stage vertical centrifugal pump driven by a motor. This pump may discharge into the open heater, the storage tank or the sewer. A Worthington dry air pump 12 in. and 30 in. by 24 in. stroke, running at 60 R.P.M., maintains an average vacuum of 29 inches of mercury.

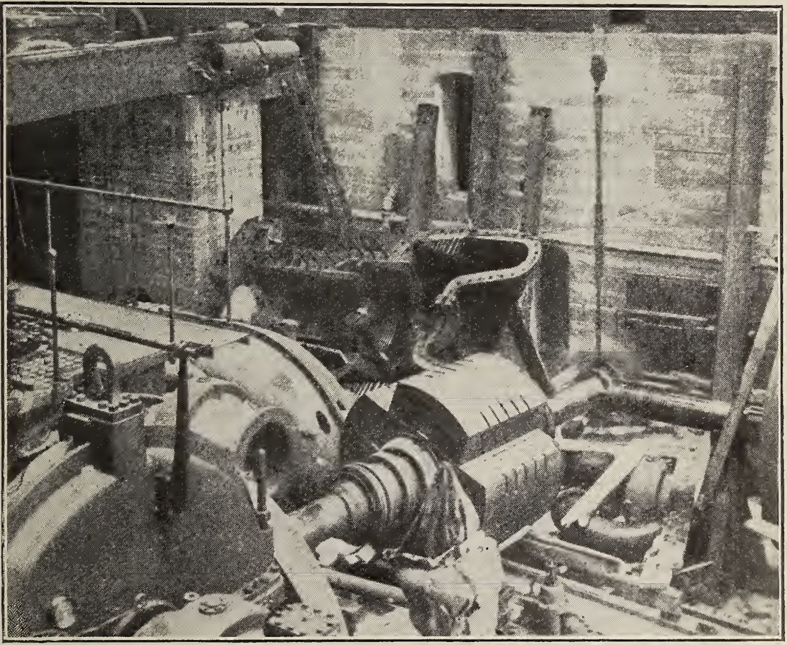


FIG. 14.—WESTINGHOUSE ROTOR.

The third condenser is supplied by the Alberger Condenser Co. It is a surface condenser, with 2 passes of water, and has a cooling surface of 25,000 square feet, made up of 8,024 brass tubes, $\frac{3}{4}$ in. in diameter. Cooling water is supplied by two Alberger centrifugal pumps geared from a DeLaval Steam Turbine. The hot well pump is a single stage horizontal centrifugal pump driven by a motor.

Exciting current may be obtained from three sources; first, for starting, from a D. C. Generator driven by a Westinghouse Automatic Compound Engine; second, from either of two motor-generator sets, the motor taking its current from one of the machines then in operation. The third source is a number of storage batteries. These are used only when all other means fail.

The electrical equipment has also received careful attention. It is one of the finest that has been put in the new stations in this district. It comprises separate galleries for the D. C. switchboard, the A. C. board, the storage batteries, the oil-switches, etc. The operator on one gallery controls the high tension oil switches which are on another gallery, thus insuring his safety.

This general description will give the reader a few of the special features of this plant. As it is one of the first stations to produce power entirely from steam turbines, it will be interesting to engineers to follow closely its progress in erection and operation. Much credit is due the engineering staff for their courage and originality in carrying out this project under such exacting conditions.

A DISCUSSION OF VARIOUS METHODS OF CHARGING FOR ELECTRIC ENERGY.

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The method or methods of charging for electrical energy from hydro-electric or any other class of electrical plants is a matter of very great importance, whether the aim be to produce a maximum of profit from a given undertaking, or simply to assess the annual cost of an undertaking fairly upon all consumers supplied.

The following is an attempt to set forth briefly the various methods of charging, and their effects upon load factor and other features affecting the distribution of charges among various classes of consumers and the various consumers in a class.

The term load factor is rightly defined as the "average output by meter" divided by the "maximum demand," but it is sometimes taken as the "average output" divided by the "installed capacity."

(1) The flat rate based upon the installed capacity is doubtless the oldest and simplest method of charging for electric power, and for small plants with a small number of customers with high load factors it is fair alike to producer and consumer. Again, in many small plants the results obtained from other methods are not such as to warrant the increased expense and trouble connected with them.

The flat rate based on maximum demand throughout a given period of time is an advance over the above in some respects. It allows the consumer much greater latitude as to the choice of motor capacity, without necessarily affecting the cost of power, to which he is justly entitled. Suppose, for instance, that a customer considers it advisable to instal a motor or lights, the capacity of which may greatly exceed his maximum demand for some considerable time in the future. He cannot justly be charged the same rate per H.P. of motor or light capacity as would be assessed upon another consumer whose maximum demand might even exceed his motor capacity. The main objection to the flat rate based on maximum demand is that it entails the taking of frequent power readings, or else the installation of a maximum demand meter with its attendant difficulties and expense. This difficulty might be met by installing a maximum demand meter where desired, and charging the cost of it to the consumer requesting such a service.

The amount of power that can be sold by flat rate from a plant of given capacity will depend upon the combined effect of the load factors of the individual customers and the tendency of the individual maximum demands to be coincident. Where the load factors of the various customers are low and where their maximum demands occur at various times of the day, it is evident that the maximum demand on the station will be much less than the numerical sum of the customers' maximum demands, and is generally a still greater amount less than the combined rated capacity of the customers' installations. In the case of commercial users of incandescent lighting this is not the case, because of the inherent tendency of the individual maximum demands to pile upon each other during one period, namely: 4.30 to 6 o'clock during the winter season. This fact is sufficient to largely account for the usual large divergence between the rates charged for electric light and for motor power.

(2) A rate per kilo-watt-hour based on the registration of an integrating watt-meter is the most widely used of all methods of charging. This is usually more or less fixed for light users, irrespective of capacity or consumption of energy, while for power users it is usually made to vary with the amount of energy consumed. This method approximates fairness only as the operating costs of the

plant, which are proportionate to output, become great relative to the fixed charges. It takes no account of load factor. For instance, a customer using a load steadily for 24 hours per day would have to pay 24 times as much as another who uses his maximum demand for the equivalent of one full hour per day only, while the former service might cost only slightly more than the latter. It takes no account of the time of use. The universal tendency of station loads to form peaks at certain definite times of the day and seasons of the year makes it inevitable that the idle capacity at other times of the day and seasons of the year can be disposed of at a profit at rates much below the normal to such consumers as can profitably utilize it.

(3) A rate per kilo-watt-hour by meter, with a minimum charge varying with the installed capacity, is a modification of the straight meter rate, and is a decided improvement in all cases where the fixed charges constitute any considerable portion of the total cost of power. It ensures that every consumer must at least pay a fixed small revenue per unit of installed capacity. Of course it has no equalizing effect outside its own range, and individual cases may and do arise where it may become somewhat of an injustice to the consumer. For instance: a large factory may wish to greatly divide its motor capacity with the expectation of securing increased economy, and thereby the load factor based on motor capacity may be greatly reduced, but at the same time the maximum demand may remain very much below the aggregate capacity of installed motors. In such a case the minimum charge based on installed capacity might often exceed the charge by meter, while the actual load factor would be quite satisfactory. In this case, as in part (1), there should be a provision whereby such a consumer could upon application have his minimum charge based on actual maximum demand instead of installed capacity. Fortunately this would be required only in the case of a comparatively large consumer to whom the cost of such a service would be insignificant.

(4) A meter rate based upon the equivalent hours' use at full capacity or upon the load factor, has many desirable features, especi-

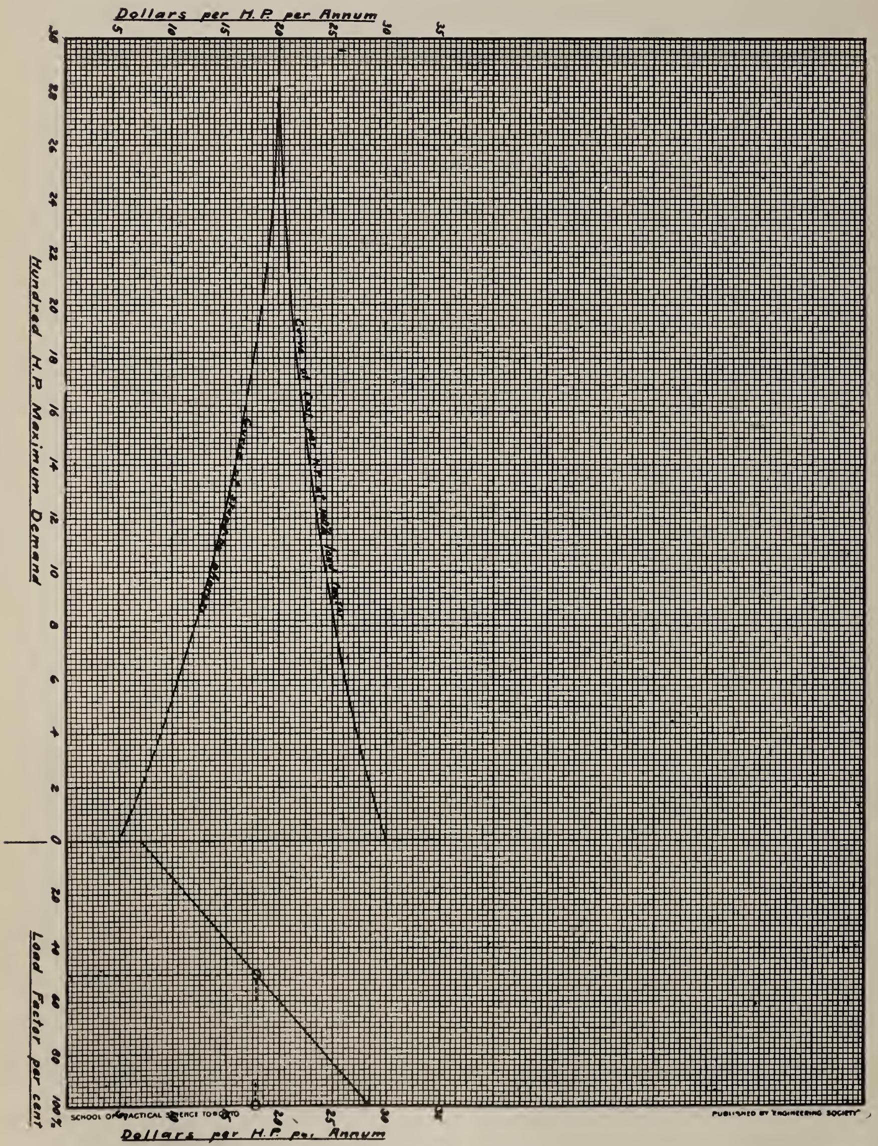
ally for the distribution of hydro-electric power. It recognizes the greater importance of load factor in preference to the minor consideration of increased cost of distribution to small consumers, and is therefore superior to any method previously mentioned. In Buffalo, where it is applied in the large business of the Buffalo General Electric Co., the rate per kilo-watt-hour varies with the ratio between the installed capacity and the metered input. The defect in the system as applied there is its failure to take cognizance of the often occurring difference between maximum demand and the total installed capacity. The rate could be made fairer for certain cases by being made to vary with the actual load factor. In one other unimportant respect it is deficient in that, as stated above, it fails to take into account the increased cost of distribution to small consumers over large ones, and in that respect it gives the small consumer an advantage over the large one, but it encourages the long hour use of light and power, and this strongly tends towards the filling up of the low portions of the station load curve.

(6) Two rate metering is accomplished by different methods, the most prominent of which is the installing of two meters, the shunt circuit of one of which is closed during certain peak hours by an electro-magnet whose circuit is closed and opened by a clock. There is therefore secured a double reading during certain peak hours. During these hours the customer would have to pay double the usual or minimum rate for such energy as might be consumed. The same result may be obtained by automatically or otherwise shunting the potential circuit of a watt-meter during all hours other than the peak ones mentioned above. By this means the consumer would pay only for a certain pre-arranged fraction of the maximum rate for all energy consumed apart from the peak hours. This method is probably one of the most effective means of influencing station-load factor. It can be made to penalize, as it were, the use of energy during certain limited hours, say from 4 to 6.30 p.m. for five months of the year, and at the same time encourage the use of energy at other hours and seasons. This method, combined with a system of variation of rates with load factor, constitutes what is

surely an ideal method of charging for electrical energy for lighting purposes. Of course it could also be applied to the sale of electric power, and would have, to a certain extent, the same effect as limited hour contracts for large motor users which have been found to be so effective in influencing load factor. It will be evident that in cases where sufficient limited hour motor contracts can be obtained to provide for the lighting peak there would not be any such great need of methods like two rate metering, and it would be a matter of choice as to which would prove the most effective.

(7) A stand-by charge of a fixed rate per h.p. to which is added a rate based upon meter registration is still another step in advance of all other methods previously mentioned for the sale of motor power. The stand-by charge may be based on the installed capacity or better still on the maximum demand, determined by frequent timing of the meter with a stop-watch or by the installation of a maximum demand meter. The meter rate is made to vary with the amount of energy used. This is the method adopted by the Cataract Power and Conduit Company in its distribution of Niagara Falls power at Buffalo. This method recognizes and can be made to adequately meet the following facts:—First, there are certain fixed charges which may be resolved into what is called the "stand-by" or "readiness-to-serve" charge; and second, there are certain charges which approximately vary with the energy used, and may be put into the form of a varying rate per kilo-watt-hour used. This system is of course very flexible, and may be made to seriously discriminate against the small consumer by making a wide difference between the maximum and minimum meter rates.

(8) For the sale of power the ideal system is one composed of a stand-by charge varying inversely with the maximum demand combined with a rate based upon the load factor. This system recognizes the fact which no other one does that the stand-by charge is less for a small consumer than for a large one. The method of applying this system will be explained by a reference to the accompanying diagram. For any given station capacity a diagram


Dollars per H.P. per Annum
5
10
15
20
25
30
35
Hundred H.P. Maximum Demand
30
28
26
24
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20
18
16
14
12
10
8
6
4
2
0
Curve of Cost per H.P. at 100% load factor
Load Factor per cent
20
40
60
80
100%
SCHOOL OF PRACTICAL SCIENCE TORONTO
PUBLISHED BY ENGINEERING SOCIETY
20
25
30
Dollars per H.P. per Annum

is prepared where the base-line in the left-hand portion represents to any convenient scale the total capacity of the station, in this case 3,000 h.p. The cost of the output of the station at the station bus-bars is taken as one end of a probability curve (here $20 per h.p. per annum), and running through an arbitrarily chosen point, on the other side of the left-hand section, here taken as $5 per h.p. per annum. Theoretically it should pass through zero, but it is for convenience taken as a small quantity. This curve represents the readiness-to-serve charges per h.p. for customers with different maximum demands. The upper curve represents the cost of delivering power to customers of varying capacity from the full capacity of the station down to that of the smallest. To illustrate its application, take the following example: suppose a customer's maximum demand meter showed a maximum demand of 200 h.p. and his metered input for a given month of 30 days was 30,000 h.p. hours. Draw a vertical line through the 200 h.p., intersecting both curves; project horizontally the upper and lower points of intersection respectively to the right and left sides of the right-hand portion of the diagram; join the two points so found. Taking the point in this line above the load factor, which in this case was 50% on a ten-hour basis, shows a charge of $18 per h.p. on his maximum demand of 200 h.p.

This method, while ideal for motor users who are uncertain as to the time of their maximum demands, is not applicable to users of light and power the tendency of which is to concentrate at certain very restricted hours.

In practice the values of the stand-by charge corresponding to certain maximum demands would be shown in tabular form in the body of every contract. In another column would be shown the corresponding differences between the stand-by curve and the curve of 100% load factor cost. These quantities, it would be explained, would be multiplied by the load factor and added to the stand-by charge.

INTERIOR ELECTRIC ILLUMINATION.

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The question of interior illumination may be looked at from so many different points of view, is subject to so many influencing or controlling factors, many of which in any given case are generally not specifically determinate, and is so much a matter of personal taste, that no hard and fast rules can be given that will hold good under all circumstances. The utmost that can be done is to indicate the various results that it is generally desirable to obtain, the best methods of obtaining these results, and the fundamental principles governing the production and correct use of artificial light and its effect upon the human eye.

The point of view of the consumer, the man who pays for the light, is that it must be sufficient, of a suitable kind, generally pleasant to the eye, in some cases it must be novel or striking, and it must always cost him, both for installation and use, as small a sum as he can possibly obtain it for. It must also be safe and reliable and require a minimum of outside attention.

The lighting company's point of view is in most respects identical with that of the consumer. The consumer must be satisfied, his bills must be just and the service safe and reliable. In addition, it must be economical of operation and show a fair profit on the investment.

It is to the interest of the lighting company that the public be encouraged in and accustomed to liberal and unstinted use of artificial light. It is equally to the company's interest that this light be used intelligently, with a minimum of waste and with a maximum of satisfactory results; and to this end it is extremely desirable that customers and prospective customers be advised as to the most appropriate and efficient methods of lighting their premises. The company's employees coming in contact with the customers, and particularly those soliciting new business, should be able to intelligently and concisely recommend the most desirable methods of lighting for any particular case, and should endeavor to so guide the customer, who of course will have the final decision in the matter, that the results obtained will give the best possible lighting consistent with the sum he is prepared to spend both for installing and use.

This paper will confine itself to a consideration of interior lighting by means of the electric current only, and I will assume that whatever methods of lighting are spoken of, the apparatus and service are each the best of their kind. This is an entirely reasonable and necessary assumption, and pre-supposes the following conditions: First, and most important of all, that the voltage supplied at the cutout is absolutely steady, except as affected by the operation of the customer's own lights. By absolutely steady, I mean that no sudden change in the consumption at another point of the system will be noticeable in the lights of the premises under consideration. Second, that variation in the voltage at the lamp is kept at as low a figure as is practicable; that the lamps, whether arc or incandescent, are of the correct voltage; that arc lamps are of the enclosed type and carefully trimmed and cleaned, and only the highest grade of soft carbons used therein; that incandescent lamps are maintained in good condition by systematic inspection and liberal free renewal, and that the entire consumption is on a meter basis; and finally, that on alternating circuits the frequency is not less than sixty cycles.

The human eye being adapted to working under the conditions existing in daylight, obviously the most desirable artificial lighting will be that which approaches most nearly to the natural. Hence we must take daylight, as we use it, or as we should use it, for interior lighting, as the guide for any attempt at a scientific and rational consideration of the subject.

The first question to be considered is that of intensity. The practical unit of light, the standard candle, though unsatisfactory in many respects, still is serviceable for making comparisons, and is in general use. The unit of intensity of illumination, the candle-foot, follows as a natural consequence. The candle-foot as a unit of illumination is that intensity of illumination obtained on a surface at a distance of one foot from a source of light having a power of one standard candle. If the light were emitted from a single point the intensity of illumination on a surface would vary inversely as the square of the distance from the point of light, and as the cosine of the angle of incidence. The light, however, never is emitted from a single point, and as will be seen later on, the application of the law of inverse squares cannot be relied upon as more than a useful guide for rough estimations. The angle of incidence need not, as a rule, be considered, since, when a brilliant illumination is required, as for reading, or the examination of goods, the surface may usually be placed at an angle of incidence whose cosine closely approaches unity.

A fundamental consideration affecting artificial lighting is the intensity of the luminous source, or the intrinsic brightness. By intrinsic brightness is meant the strength of light per unit area of light giving surface, the unit adopted being one candle power per square inch. The approximate intrinsic brilliancies in c.p. per square inch of some sources of light are given below.

Sun in zenith	600,000
Sun at 30 deg. elevation	500,000
Sun on horizon	2,000
Open arc light	10,000 to 100,000
Open arc light crater	200,000
Enclosed arc lamp with opalescent inner globe	75 to 100
Calcium light	5,000
Nernst "glower"	1,000
Incandescent lamp, clear	200 to 300

Incandescent lamp, frosted	2	to	5
Acetylene flame	75	to	100
Welsbach light	20	to	25
Kerosene light	4	to	8
Candle light	3	to	4
Gas light	3	to	8

The intrinsic brilliancies given for the sun at different positions in the meridian are, of course, the apparent brilliancies at the earth's surface. The actual brilliancy does not vary, the differences being due to the increased absorption of light by the atmosphere when the rays are nearly horizontal. A consideration of these differences brings up and illustrates a point in artificial lighting that is often overlooked, but yet is of primary importance in determining the amount of light required in any given case. One would hardly suppose that sun-light at midday was more than a hundred fold as intense as at sunset. Yet such is the case, and moreover when not in the direct rays of the sun, we can see to read almost equally well at any time of the day from sunrise to sunset. This shows that within a quite wide range of absolute brightness of illumination, our vision is about equally effective for all ordinary purposes. Provided the parts of the visual picture retain their relative brightness, the distinctness of detail does not vary materially with great changes of absolute brightness. This must not be construed as a statement that variation in intensity or unsteadiness is of little consequence. Sudden variations in intensity are extremely trying to the eye, and must by all means be avoided. It is, however, an enunciation of the principle that brilliancy of illumination has relatively less effect upon the eye than some other properties that will be considered later.

It will also be observed in the above table that there is a great difference in the intrinsic brilliancies of arc and incandescent lamps when with and without diffusing globes. This, of course, is due almost wholly to the immensely greater radiating surface of the globe over the carbon arc or filament, and illustrates the importance of having as great an area as possible from which the source of light may distribute its rays. In a room lighted by daylight, the source of light becomes practically the whole surface of the window panes. A well lighted office will have windows whose light emitting area is equal to not less than about one-eighth of the floor area. Yet the projected surface of an outer arc lamp globe seldom exceeds one square foot. The projected surface of a frosted 16 c.p. lamp is about six square inches, both of which areas are out of all proportion to the surfaces to be lighted.

If the radiating surface be not thus distributed, every time the eye catches a direct ray, an after image will be formed upon the retina, fatiguing it, and causing the pupil to contract. When the eye then looks away from the lamp, the reflected light appears dim owing to this contraction, and the room seems to be insufficiently lighted, when quite the reverse may actually be the case. This contraction and enlargement of the pupil is the cause of annoyance in flickering or unsteady light.

Hence to approach the conditions of daylight, the enclosing globes for interior lighting must be of translucent material, and these globes should have as great a light emitting surface as mechanical considerations and artistic effect will allow. The question as to how much light is cut off by such globes will be taken up further on.

Now as to color. It is generally desirable that artificial light shall have the color values of diffused daylight, this white light being the one to which the eye is accustomed and adapted. This is particularly necessary in stores where certain kinds of dress-goods, carpets and furniture are sold, in textile mills and picture galleries, and wherever colors are to be matched or closely examined. In certain other cases, however, such as in domestic illumination, a light slightly richer in yellow and of softer tones, may be preferred. Except for scenic effects, a preponderance of any other color than yellow should be studiously avoided, for not only does such an excess injure color perception, but the luminosity of such rays compared with that of yellow is low.

The general effect of colored lights is to accentuate objects of the same color as the light, and to change or dim all others. The following table given by Dr. Louis Bell, shows the effects resulting from lights of different colors falling upon differently colored fabrics. The fabric colors are the ordinary commercial pigments. Thus a blue light falling upon a pigment yellow fabric will show green. Falling upon a light blue, it will show the fabric as a very vivid blue. An ordinary white object will appear of the same color as the light falling upon it.

We have to deal with white light tinted with other colors as a rule, so that generally the effects will not be as marked as is indicated in the table.

Arc lights vary very much in color, from a clear white in short arcs to a bluish white or violet in long ones. Incandescent lamps, if worked at low efficiency, are yellow, and become more and more nearly white as the efficiency increases. For this reason, if for no other, lamps with an efficiency lower than 3.8 or 4 watts per candle are undesirable. From the point of view of the color of the light emitted, the greater the efficiency above this minimum the better, as the limiting efficiency due to the lamp life will be reached before that due to the intensity.

These considerations of color divide interior lighting into two separate classes, namely, those cases in which white light is necessary or preferable, and those cases in which such a light is not necessary or is even undesirable. In general terms, it may be said that the arc light should be used in the first case, and the incandescent in the second. When we come to consider the question of distribution and arrangement of light, it will be found that interior lighting is again divided into two classes: one, more appropriate to the arc light and the other to the incandescent, and it will further be found that these two divisions very nearly coincide. That is to say, in any given case, where arc lighting is preferable from a color point of view, arc lighting will generally be preferable from considerations of light distribution and arrangement.

Original Color of Fabric.	Color of Light Falling upon Fabrics.					
	Red.	Orange.	Yellow.	Green.	Blue.	Violet.
Black	Purplish-Black.	Deep Maroon.	Yellow-Olive.	Greenish-Brown.	Blue-Black.	Faint Violet-Black.
White	Red	Orange	Light Yellow.	Green	Blue	Violet.
Red	Intense Red.	Scarlet	Orange	Brown	Violet	Red - Violet - Purple.
Orange	Orange-Red.	Intense Orange.	Yellow-Orange.	Faint Yellow, slightly Greenish.	Brown, slightly Violet	Light Red.
Yellow	Orange	Yellow-Orange.	Orange-Yellow.	Yellowish-Green.	Green	Brown tinged with faint Red.
Light Green	Reddish-Gray	Yellow-Green	Greenish-Yellow.	Intenser Green.	Blue-Green	Light Purple.
Deep Green	Reddish-Black.	Rusty-Green.	Yellowish-Green.	Intenser Green.	Greenish-Blue.	
Light Blue	Violet	Orange-Gray.	Yellowish-Green.	Green-Blue	Vivid Blue	
Deep Blue	....	Gray, slightly on Orange.	Green-Slate	Blue-Green	Intenser Blue.	Bright Blue-Violet.
Indigo Blue	....	Orange-Maroon.	Orange-Yellow (very dull).	Dull Green.	Dark Blue-Indigo.	Deep Blue-Violet.
Violet	Purple	Red-Maroon.	Yellow-Maroon.	Bluish-Green-Brown.	Deep Bluish-Violet.	Deep Violet.

The relation of reflection and diffusion to practical illumination is of great importance, and must be carefully considered for each individual case. The underlying principles may be easily stated, but it is often difficult to so apply them as to obtain satisfactory results.

Regular reflection, when the incidental reflected rays lie in the same plane, such as occurs from mirrors and highly polished metal surfaces, is generally a simple matter so far as direction is concerned, but diffuse reflection is of a much more complicated character, and it is that kind with which we usually have to deal.

In diffuse reflection, the light is reflected irregularly in every direction owing to the roughness of the reflecting surface. If the surface be a comparatively smooth one, as for instance a painted wall or ceiling, or some grades of wall paper, the reflection will be both regular and diffuse, there being a general predominant direction of reflection, plus a certain amount of diffuse reflection. This condition is the one that usually obtains in interior lighting.

If the reflecting surface be colored, the reflected light will of course be colored or tinged. The more minute the roughness of the surface, the greater will be the selective reflection, and hence the greater the coloration of the light, owing to the selective or cumulative effect of each successive reflection. This coloration of the light, owing to reflection, is generally greater, and has more effect upon the eye than the original color or the light itself, and unfortunately these two colorations cannot, as a rule, be made to neutralize one another, so that in planning the general color tone of a room to be illuminated, it must be remembered that if the walls are strongly colored, the dominant tone of the illumination will be that of the walls rather than that of the light.

There is an actual loss of light with every reflection, due to absorption by the reflecting surface. In direct reflection, this loss varies greatly with the angle of incidence, the total loss being from ten to seventy per cent. for highly polished surfaces. In diffuse reflection, the loss depends very little upon the angle of incidence, but greatly upon the nature of the surface and upon its color. The more minute the irregularities of the surface, the greater will be the selective reflection, as stated before, and the greater the loss. The darker the color, the greater will be the loss, owing to the greater absorption of the yellow and orange rays.

Hence the color and character of the reflecting surface affect the total quantity of the useful light. A table showing the relative values of some reflecting surfaces, mostly paper, is given below.

DIFFUSE REFLECTION.

Material.	Coefficient of Diffuse Reflection. K	$\left(\frac{1}{1-K}\right)$
White Blotting Paper	.82	5.56
Chrome Yellow Paper	.62	2.63
Orange Paper	.50	2.00
Clean White Pine	.45	1.82
Yellow Paper	.40	1.67
Light Pink Paper	.36	1.56
Light Blue Paper	.25	1.33
Light Brown Paper	.20	1.25
Green Paper	.18	1.22
Dark Brown Paper	.13	1.15
Vermilion Paper	.12	1.13
Dark Blue Paper	.12	1.13
Black Paper	.05	1.05
Black Cloth	.012	1.01

It will be seen from this table that the lighter the color of the surface the higher the coefficient of reflection. The rough fibrous wall paper now popular also has a high coefficient.

Now the effective illumination at any point in a room will be the sum of the direct and reflected lights. The reflected light will be composed of some light reflected once, a smaller part reflected a second time, a still smaller part reflected a third time and so on, each additional reflection reducing the amount in the proportion of the coefficient of reflection. Expressing this concretely, if L be the light received directly the total light received will be $L + KL + K^2 L + K^3 L$ and so on where K is the coefficient of reflection. This series approaches the limiting value $L\frac{1}{1\text{-}K}$ as the number of terms is indefinitely increased. The expression $\frac{1}{1\text{-}K}$ is the factor by which the direct light at a point must be multiplied to obtain the total light there. This will always exceed unity. Its value for average conditions will probably be between 1.25 and 2.00.

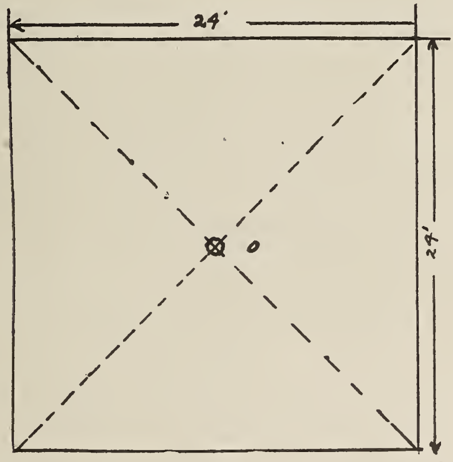

FIG. 1

In applying these principles to practical illumination, let us first take a simple concrete case. Assume a room 24′ x 24′, Fig. 1, to be lighted sufficiently that one may easily read in any part of the room. Let the walls and ceiling have an average diffusive coefficient of .34, which will make $\frac{1}{1\text{-}K} = 1.51$, say 1.5, increasing the effective value of the radiant by 50 per cent. Let the light be 8′ above the floor, and assume that the plane to be illuminated is 3′ above the floor. A good light to read by would be one candle foot. Take first the case of a single light in the centre of the room at the point

O, Fig 1. The greatest distance from *O* to a corner *P* of the plane is 17.7′, which would require that the light have a power of $(17.7)^2$ or 313 candles if there be no reflection from the walls, etc. With the reflection assumed, the light must be $\frac{1}{1.5} \times 313 = 207$ c.p., say 13 sixteen c.p. lamps. Such an arrangement would be absurd. The centre of the room would be so brightly illuminated that the walls and corners, though actually well lighted, would appear dim by contrast. Let us try dividing the light into four clusters, *a*, *b*, *c*, *d*, Fig. 2. Then to light the same corner *P* with the minimum of one

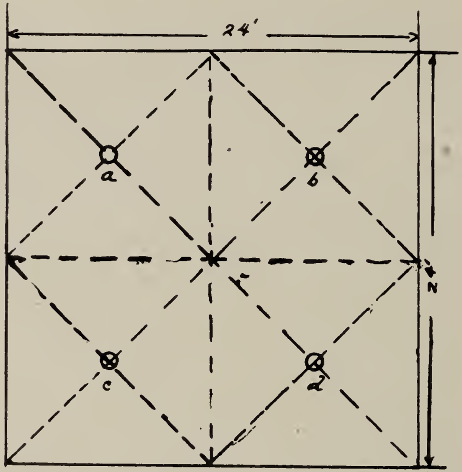

FIG. 2

candle foot, we must figure the distances of each illuminant, *a*, *b*, *c*, *d*. These are 25.9′, 15.7′, 15.7′, and 13′ respectively, and for each candle power at these points the light received at *P* will be $\left\{\frac{1}{(25.9)^2} + \frac{1}{(15.7)^2} + \frac{1}{(15.7)^2} + \frac{1}{(13)^2}\right\} \times 1.5 = .0233$ c.p. Hence to obtain one candle foot at *P*, each of the lights *a*, *b*, *c*, *d* must be of 42.9 c.p., or 172 c.p. altogether, against 207 in the first case. This is a great improvement, not only in economy, but also in results, for whereas the maximum illumination on the reading plane in the first case was

12.5 candle feet, the maximum in the second case is only about 3.5 candle feet.

Placing five lights as shown in Fig. 3, each would have to be of about 29.2 c.p., and the maximum illumination on the reading plane would be about 3.1 candle feet under the centre light. That is to say, five 32 c.p. lamps arranged as in Fig. 3 give better illuminating results than thirteen 16's clustered in the centre of the room.

Obviously then, with a fixed minimum illumination, the greater the distribution of the illuminants the greater the economy and the better the lighting, and this general principle is applicable for all classes of interiors. There will be many modifying circumstances, such as the necessity of additional brilliancy at certain points, the fact that the corners of rooms need seldom have the light required even for general illumination, the shape of the interiors, and location of furniture, machinery, belts, pillars or other shadow casting objects, and finally the location of doors, windows, pictures or other objects affecting the wall diffusion.

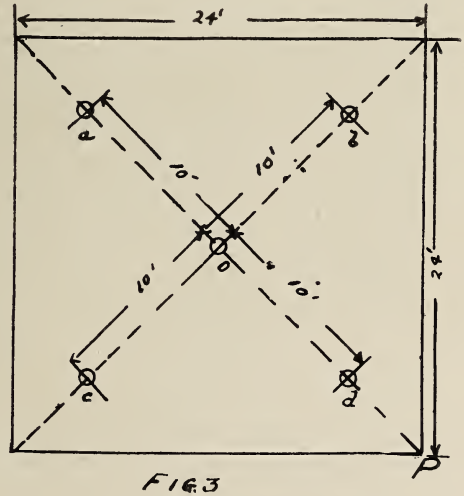

FIG. 3

This division of the illuminants must not be carried too far, as the total abolition of all shadow is undesirable, especially in domestic lighting. Such a condition produces a flat appearance in the room that is very trying to the eyes. Generally speaking, however, the number of divisions of the light will be limited by the size of the units economically desirable and by the cost of installation. It is not desirable to have 110 volt incandescent lamps of less than 6 or 8 c.p.

For domestic lighting it is not so necessary that the results shall nearly simulate daylight, either as to intensity or distribution. It will give an equally good effect and at a lower cost if only a very moderate general illumination be provided, adding to this whatever additional light is required for special purposes. The controlling feature in domestic lighting is generally the artistic effect desired, and this confines us to the use of either chandeliers or side brackets, or in some cases to ceiling lights. Drop lights, either suspended by cords or by rods, are not desirable. Portable drop lights, however, are very efficient where such lighting is appropriate, and their use should be encouraged. Side brackets generally give a better distribution of light than do chandeliers even in small rooms, and they also are more easily placed so that the light falls just where it is most required. They should not be placed too low, however, which I think there is generally a tendency to do. Both brackets and chandeliers should have widely extended arms, and the lights should preferably be so held as to point downwards.

The height at which lights should be placed will depend upon the height and character of the room, the diffusive power of the walls and ceiling, the strength of the lights and the strength of the light required on the lighted surface, and the height of the latter. It is usual to assume the height of the illuminated plane as 2½ or 3 feet above the floor. Of course, incandescent lights, not controlled by wall switches, must be within convenient reach, which requires that the sockets be at a height of not more than six feet in residences, and seven feet in stores and offices. This brings the light lower than it is generally desirable. The lower the light the greater the direct illumination, but the higher it is placed, the greater the diffused illumination, and above all, the higher the light the less will be the liability of direct radiation to the eye. This must be avoided by all means, even if the lamps have to be placed so high as to sacrifice considerable light. A much better general effect will be produced if the lights be high up, especially in large interiors where the eye is more liable to catch direct rays. For such cases, some authorities give the correct height as about .6 times the distance between lights.

I think that it is better to consider each interior independently, placing the lights on wall switches as high as the desired intensity of illumination will allow, and those controlled by socket switches, as high as the socket can be conveniently reached.

As to the use of shades and reflectors in domestic lighting, their importance is largely dependent upon the conditions. For drop lights, where the walls and especially the ceilings are finished in a light color, I do not think that flat reflectors either increase or improve the light to any extent. One is so accustomed to seeing a shade of some kind, however, that the lamp looks incomplete without one, so that a shade or reflector of some kind should invariably be used. With darkly colored walls and ceilings, flat reflectors are of great assistance in increasing the lighting, to such an extent indeed, that when used under such conditions the coefficient of diffuse reflection of the reflector is of more importance than that of the walls and ceiling. The white porcelain shade gives the best results, and the best size to use will depend on the height of the lamp, the object being to deflect the light rays that would otherwise reach the ceiling and upper parts of the walls. The absorption of these reflectors seems to be about 13 per cent. The fluted shade gives a slightly better light diffusion than the smooth, but is more difficult to keep clean. Mirror reflectors should be avoided in domestic lighting.

All lights, other than drop lights or ceiling lights, should be shaded by some form of bell shade or by an outer globe. The best of all from light distributing point of view are the holophane, and their use should be recommended. Next to these come the translucent poreclain and ground or etched glass. Cut glass is of little use, as are all colored glass shades or globes, and those casting a streaked or mottled shadow should be especially avoided.

The primary requirement of shades and globes is that they shall soften and diffuse the light. They do this, of course, at the expense of some light, so that all calculations must take into account this loss. Many tables have been given showing the loss, but they vary between pretty wide limits, very much depending upon the thickness of the shade and the character of its surface. The following table may be used for average conditions:

Material.	*Per Cent. Loss.*
Clear Glass	10
Alabaster Glass	15
Ground Glass, Light Grinding	15-20
Ground Glass, Heavy Grinding	25
Light Opal Glass	25-40
Heavy Opal Glass	40-60

It must always be remembered that, though the use of shades and globes reduces the total light, the resulting diffusion and lessening of the intrinsic brilliancy more than compensates therefor. That is to say, a room, part of whose light is cut off by properly arranged shades, will appear better lighted than if the whole light were employed unshaded.

The whole subject hinges upon the fact that the eye will adjust itself to the maximum intensity of illumination, adjusting the admission of light to the retina to that maximum, so that every other part of the field of vision appears dim owing to the contracted state of the pupil.

The use of ground glass or frosted incandescent lamp bulbs should be much greater than it is. Personally, I think that every light not shaded by a globe or deep bell shade should be frosted, and that even when so shaded it should be frosted if the lamp bulbs can be seen from any part of the room as ordinarily occupied. To this end, the incandescent lamp department should be equipped with the simple apparatus and few chemicals necessary for frosting the lamps as received from the manufacturer, reserving only a few clear glass lamps for use in special cases, as when the lamp is enclosed in an outer globe. I think that the frosted lamp should be regarded as "standard," and always supplied to customers, excepting when clear glass is specifically called for. The lamps might be given two different degrees of frosting, a light one for those to be used with bell shades, and a heavy one for those to be used with flat shades. In any case the amount of frosting should always be uniform. The light cut off by this frosting varies between about three and seven per cent.

The actual amount of light required for residence lighting can be given in candle feet with a fair degree of accuracy, but to give it in watts per square feet or even in number of square feet per incandescent lamp involves the questions of reflection, distribution and loss of light above considered, besides that of lamp efficiency.

I think that the following figures in candle feet will give good lighting effects. The column marked square feet per 16 c.p. lamp, and watts per square foot, can only be regarded as approximate, and are figured on the assumption that the lights are as fairly well distributed as is ordinarily possible in domestic lighting, that they are shaded by efficient shades, are frosted, and are 56 watt lamps.

It might be objected that the difference between the light required for rooms having light or dark colored walls is not so great as the previous emphasis of the advantages of light colored walls seemed to indicate. The table, however, was compiled on the assumption that the shades were so selected as to deflect much of the horizontal light downwards. Nevertheless, reflection and diffusion by shades can never equal, in good effect, that of light colored walls and ceilings.

I think that the best way to consider the subject is to assume the candle feet required in a given case, and from that deduce the lamps required to give that illumination, taking into consideration all of the above controlling facts and allowing a liberal margin for loss in reflection due to the discoloration of walls and shades, and for deterioration of the lamps.

	Candle Ft. for Gen. Illum.	Sq. Ft. per 16 c.p. Lp.		Watts per Sq. Ft.		Notes.
		Light Walls and Hangings.	Dark Walls and Hangings.	Light Walls and Hangings.	Dark Walls and Hangings.	
Halls	.5	120	90	.47	.62	
Dining Rooms......	1.0	60	45	.93	1.24	Main light over centre of centre table; side lights for side tables if necessary.
Reception Rooms....	1.5	45	30	1.24	1.87	Brackets or wide armed chandeliers, preferably 8 c.p.
Bed Rooms	.75	84	60	.67	.93	Side brackets at convenient points.
Library	1.0	60	45	.92	1.24	Side brackets with portables.
Sitting Rooms......	1.0	65	45	.86	1.24	

There are certain cases when a single source of light may be preferred by the customer, even in fairly large interiors, as over the centre of a dining-room table, or in a square hall. Here a single 16 c.p. or 32 c.p. lamp may be employed, placing it as high up as possible, and enclosing it in a ground glass globe. These single lights will be powerful enough only for very small rooms. For larger rooms the meridian lamp may be substituted, and produces a very pleasing effect when placed well above the line of vision. For large interiors of every kind, where a unit larger than the ordinary incandescent is desired, these lamps are very serviceable.

General office lighting partakes somewhat of the character of domestic lighting in that as a rule the units required are small, and there is considerable assistance from wall and ceiling reflection. The illumination, however, must be greater. It should not fall below one candle foot for general illumination, and the customer may require as much as four candle feet at particular points, but this should be discouraged. Three candle feet seems to be the maximum desirable intensity for such lighting. Large offices may use enclosed arc lamps with very satisfactory results, but these will often give more intense illumination than is desirable, when Nernst or Meridian lamps may be substituted.

Nernst lamps have a high efficiency as compared with the ordinary incandescent, about two watts per spherical c.p., but are not as yet available for all circuits. The two and three glower lamps seem to give good results where 220 volt. A. C. is used, but for larger units the arc lamp is to be preferred. I think that one reason why the Nernst and Meridian lamps are so well liked is that the lamps and globes themselves are graceful and simple in outline and are designed to give a maximum of diffusion and reflection.

The lighting of small stores is generally the most unsatisfactory of all. This is often in part due to the merchant not renewing his lamps when required, or keeping the bulbs and shades clean. It is still more often due to improper arrangement and insufficient number of lights. The conditions require abundant light to give good results, and it is in just these places that economy is most necessary. Very many of these small stores look dingy when lighted even by a liberal number of incandescent lamps, owing to the yellowness of the light and the generally dark and mixed character of the surroundings. The remedy is to replace the small incandescents by small arc lamps or Nernst lamps taking the same power, placing them high up and using efficient diffusing shades. At the same time the merchant should be induced to so arrange his goods as not to obstruct the light, and in small dry goods stores he will get better lighting if he will line the walls with light goods and place the dark ones upon the tables. The general illumination for these stores should not fall below one candle foot, which will usually require one 16 c.p. lamp for about every 50 or 60 sq. ft. But better results may be obtained by using one arc lamp where from 6 to 10 lights are required, if the shape of the room lends itself to effectual lighting from a single source.

Large stores are generally more easily lighted than small ones. They are conveniently divided into sections by the arrangement of the pillars and passageways and the ceilings are higher, and in modern buildings are almost invariably painted white, or are given a very light tint. Here the arc lamp seems to be entirely suitable. The lamps should be hung in the aisle centres or on the centre lines of counters, equidistant and at a uniform height. The most effective height seems to be about 9 feet, though this will depend somewhat on the illumination desired. The conditions being, comparatively speaking, constant, the amount of light required can be much more accurately estimated than in the case of small stores. Each 500 watt arc lamp should light a space of from 400 to 600 sq. ft., depending upon the character of the goods, or from 1.25 to about .8 watts per sq. ft. The general tendency is to give too bright an illumination. In several large stores that I have examined the watts per sq. ft. ranged from 1.5 to 2.0. The result was an unnecessarily bright light that was trying to the eyes. Mr. W. D. Ryan recommends from .75 to 1.5 watts per sq. ft., even falling as low as .5 in some cases. Unfortunately the distance between aisle centres is, as a rule, not more than 16 or 18 feet, so that it is often difficult to so arrange the lights that there will not be light and dark spots. A good point to remember is that an endeavor should be made to have the bright spots fall upon the counters and goods, and the dark spots upon the wide aisles. But this must not be done by hanging the lamps out of line with one another.

The size of the lamps need not necessarily be the same in every case. It is better to adjust the size of the lamp to the light required than to burn too large or too small a lamp merely because that size has been adopted as standard, even though this multiplication of sizes will entail additional work in the storeroom. Where the lighting company can control or influence the selection of lamps, three or at least two different sizes should be used.

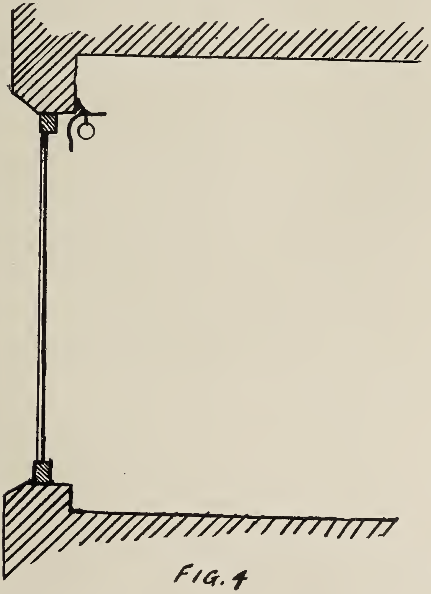

FIG. 4

The figures of watt consumption per sq. ft. given above should determine the size of lamp to be used in any given case, when the general arrangement of the aisles or pillars fixes the number and location of the lamps.

Arc lamps should be operated on 110 volt. circuits in preference to the 220, owing to the extremely blue color of the high voltage arc, and each should have a conveniently placed switch to allow of individual operation.

In the lighting of store windows the brightest light of all is required. This light should come from the front of the window, the lamps being placed so high up and near the glass that they are invisible from the street. This is easily obtained with incandescent lamps by placing a row of lamps in a trough-shaped metal reflector as shown in Fig. 4. For large and high windows the 16 c.p. lamps should be spaced about 15 inches apart for light goods, and about 12 inches for dark goods. Small windows will require lamps about 18 inches apart. The bulbs should not be frosted.

I do not think that rows of lamps arranged on the sides or bottom of the window give effective lighting in any case, or that any other system can equal in effect that of placing a single row of lamps as shown. Unfortunately the window lighting for many stores requires to be of as white a color as that required for the interior, so that the merchant should, if possible, be induced to use small arc or Nernst lamps in his windows in such cases. If an efficient form of reflector be used, a single small arc lamp, taking power equivalent to about six incandescents, will light a medium-sized window very effectively, the lamps being still placed high up near the front of the window, and if necessary, shielded from view from the street by a metal reflector.

Two or three Nernst lamps will give still better results.

In shop and mill lighting the conditions are not so rigorous as in stores, in that the lamps may generally be placed at the exact location desired. But the diffusing value of the surroundings is lower. Arc lamps are preferable to incandescents and are more economical if the interior be large and with high ceilings.

The following table, collected from a number of installations, gives the approximate floor area that should be allowed for various classes of shops and mills using 5 ampere lamps with efficient shades and reflectors:

Building.	*Sq. Ft. per 5 Amp. Lamp.*
Machine shops with high roofs, large machines and many belts	400
Machine shops with low roofs, large machines and many belts	500
Machine shops with few obstructions	650
Textile mills with high looms, white goods	420
Textile mills with high looms, colored goods	380
Textile mills with low looms, white goods	450
Textile mills with low looms, colored goods	400

These figures are on the assumption that a good light is required in every part of the room. In large machine shops and erecting shops such a light will be required at certain points only. Incandescent lamps may be used at these points, and the general illumination reduced to about one arc lamp for about 1,000 or 1,200 sq. ft. Reflectors should be used in all cases.

These general statements as to interior lighting may be summarized as follows:

The intrinsic brilliancy of the source of light should be as low as possible, which will be most readily obtained by enclosing the light in translucent globes. The light should be evenly distributed, which is best obtained by using many small units. It should be well diffused by light colored walls and ceilings, and by efficient reflectors. It should be kept out of the line of vision by placing the lamps as high up as circumstances will allow. It should be of suitable color, and finally the lamp or fixture and shade, unless intrinsically ornamental, had better be severely plain and as inconspicuous as possible.

SOME FEATURES OF MODERN CORLISS ENGINES.

A. K. Spotton, '94.

The fact that the direct-connected electrical generator has almost entirely superseded the belt-driven type which was at first used for light and power purposes, has led to radical changes in the design of the engines employed.

Commercial considerations have always considerable influence in determining the purchase of a machine, and with the keen competition in this line of machinery, has come the tendency of electrical companies to offer generators of as high a speed as was conformable with first class economy in the engines. These circumstances have forced the engine builders to construct four valve automatic cut-off engines, mainly of the "Corliss" type, running from 125 to 175 revolutions per minute, the usual speed being 150 revolutions per minute. The old familiar type of Corliss valve gear with its long rock arms, heavy wrist plates and vacuum dash pots of uncertain action has been abandoned for a system with moving parts of less inertia, and a positive quick-acting cut-off. As is bound to be the case, designers differ as to the best methods of obtaining these ends, and the result has been the development of two types differing mainly in the method of governing the cut-off.

The first of these is provided with a shaft governor directly connected to the steam valves through a wrist plate motion, the valve travel and opening being varied by shifting the eccentric in a manner similar to high speed engines of the familiar type. The chief disadvantage of this system is the fact that the friction load of the valve gear has considerable effect on the governor, and as the valves are unbalanced the regularity of the governor is dependent to a large extent on the efficiency of the oiling system, and thus an element of much uncertainty is introduced. Another drawback is the great weight required in a governor of this type to successfully control the cut-off on both cylinders of a compound engine,

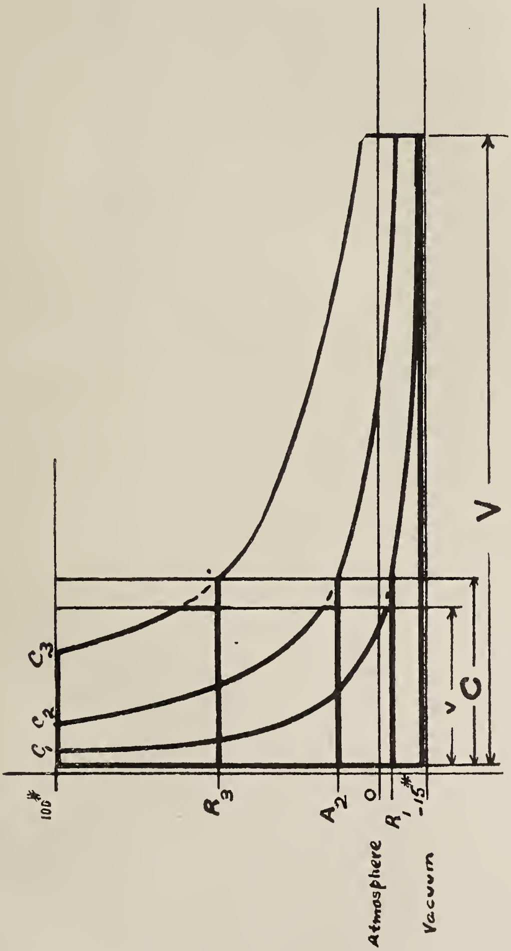

Fig-1.

and it has been the practice of some builders to put a fixed cut-off corresponding to the rated load of the engine on the low pressure cylinder. This condition is permissible in an engine which is carrying a practically steady load somewhere near its rated capacity, but when the load is a widely varying one and particularly when it is carried by two or more engines driving alternating current generators running in parallel, the detrimental effect of this method of governing becomes apparent. Figure 1 shows the combined cards of a compound variable cut-off engine.

V and v represent the volumes of low and high pressure cylinders respectively. C_1, C_2, and C_3, the points of cut-off in high pressure cylinder corresponding to respectively a light load, rated load and overload. C is the constant cut-off in the low pressure cylinder. R_1, R_2, and R_3 are the receiver pressures corresponding to these points of cut-off. It will thus be seen that as the load goes off, the receiver pressure drops and the high pressure cylinder carries the greater portion of the load. As the load increases beyond the rated capacity of the engine the reverse conditions exist and at nowhere except the rated load is the load evenly divided between the two cylinders. The conditions of driving alternators in parallel require that impulses given to the cranks be as even as possible, and the overload capacity demanded in modern electrical plants is 50%, so that to get the best results the cut-off on both cylinders should be controlled by the governor. This, in the other type of high speed Corliss engine, is accomplished in the usual way by employing a trip motion and controlling the period of unhooking by a governor of the flyball or inertia type. A single cylinder engine of this style is shown in Fig. 2. The absence of wrist plates and the general lightness of the moving parts is noticeable. The closing of the valves is accomplished by steam pressure, which acts on a small plunger to which the valve arm is attached. There is also provided an air cushion which allows the valve to come to rest gently after the point of closure. This arrangement gives an extremely rapid and positive cut off, permitting a high speed of rotation. In the modern Corliss engine much care is given to the manufacture

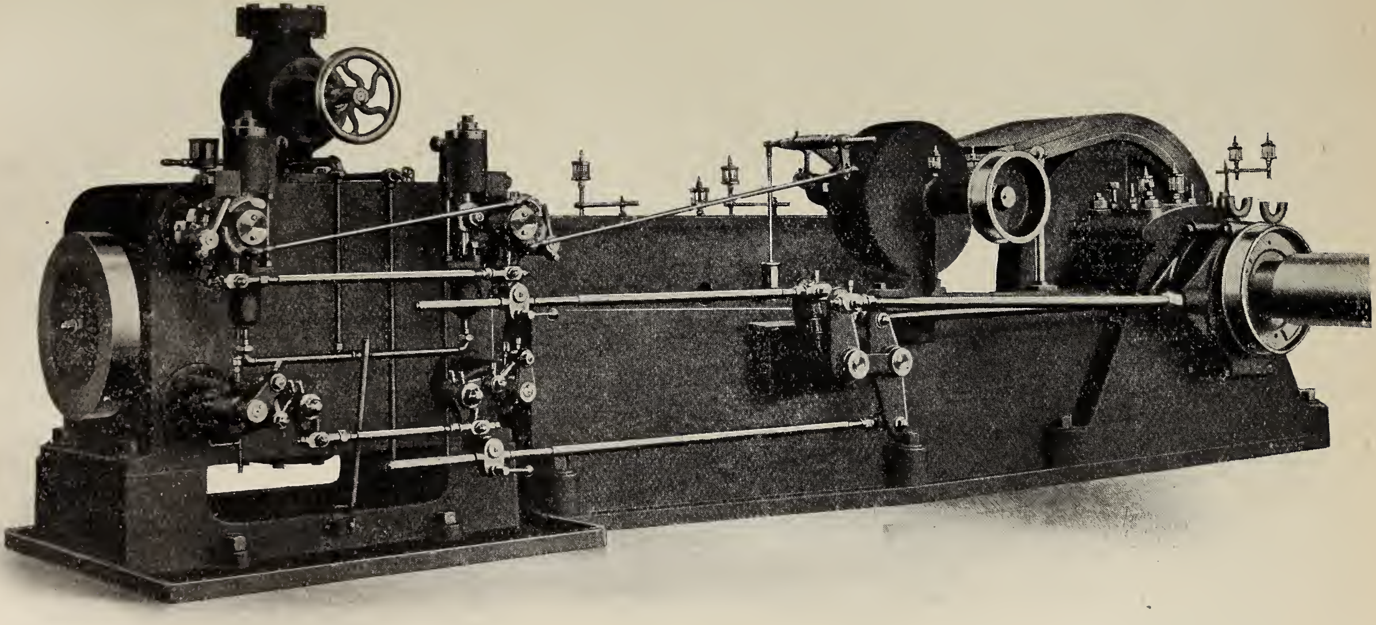

FIG. 2.

of the valves and their seats. The laborious method of scraping the valve and its seat to a steam-tight fit has been superseded by lapping the seat out with a lead lap and emery, which gives a perfect bearing seat. The valve is ground to gauge in a grinder to suit the seat, and a steam-tight valve is assured without the need of any hand fitting. Some makers furnish ground seats which are pressed into the cylinder casting and when worn can be removed and replaced by new ones. The frame is a radical departure from the type long associated with the Corliss engine, and commonly known as the "Girder" frame. As steam pressures and speeds of rotation increased, a point was reached at which this type of frame was wholly inadequate. It was hence replaced by a frame in which the pillow block end was very massive and connected to the cylinder by the circular guide casting. This has in turn given place to a frame cast in one piece and resting on the foundation for its entire length. This frame is fitted with a main bearing with side wedge adjustment, and of such a size that the pressure per square inch of projected area does not exceed 130 pounds. For direct connected engines running alternators in parallel with their heavy fly wheels and generator rotors, this consideration results in extremely large bearings which are usually provided with water cooling pipes attached to their lower shells. Attempts have been made to give these bearings a vertical wedge adjustment, but this was found to be unsatisfactory, and any wear of the main bearings is allowed for by a layer of thin shims placed between the generator housing and its bed plate, and which may be removed as the shaft goes down. The cylinders are lagged with a non-conducting material covered by sheet metal. Steam jacketting has been generally abandoned except in special cases, although some makers still jacket the heads. This somewhat lowers the steam consumption, but with the use of superheated steam the advantage of jacketting is a doubtful quantity. The crank and crosshead pins have been materially increased in size, and in the better makes of engines they are made of steel which is case-hardened and ground, giving a surface which ensures cool running. This matter of pin surface has a very important bearing on the running qualities of the engine, and with a properly hardened and ground pin it is possible to run cool a pin whose dimensions are much smaller than modern practice dictates. A greater pressure than 1,200 pds. per square inch of projected area on the crank pin is not considered good practice, yet a well ground, hardened, and properly set pin has been known to run many years with no trouble subjected to nearly double this pressure.

The oiling of an engine of this type is of great moment, and too much care cannot be taken to see that all wearing parts are furnished with a copious supply of oil. The usual procedure is to employ an automatic oiling system which supplies the oil to the engine through a system of pipes under pressure. This pressure is obtained either directly from the oil pump or from a tank raised above the level of the engine oil cups. The latter method is preferable as it maintains a constant pressure without complicating the system. The oil flows by gravity from the tank to the oil cups, which are of special design to stand the pressure put on them, and are of the sight feed type. They also are provided with an oil reservoir and can be used as ordinary sight feed cups, should anything happen to prevent the pressure system from working. From the cups the oil is all collected and discharged into a filter under the floor of the engine room and from there is pumped back to the tank. With this free delivery of oil and high speed of rotation, there is a great liability of having the oil thrown over the engine and floor, and to prevent this it has become the custom to enclose the crank and eccentrics more or less completely with sheet metal shields which effectually prevent this throwing of oil. So important has this matter become that the making of these sheet metal shields alone has become a business of magnitude.

In making out a specification for a direct connected engine on which a manufacturer may tender, the following information should be furnished by the engineer:—Capacity of generator; number of revolutions per minute; steam pressure carried on boilers; whether engine is to be single cylinder, cross compound or tandem compound; whether engine is to run condensing or non-condensing; the probable back pressure if the exhaust is to be used for heating, drying or other similar purposes; whether generator is direct current or alternating; if the latter, number of cycles and phases.

The above information is necessary for a manufacturer to intelligently tender on an engine for a given service with a view to getting the best results. When this information has been given the following clauses should be inserted in the specifications as they enumerate qualities which are essential to a first class Corliss engine of the high speed type.

Valves and Seats.—The valve seats if circular are to be ground out and the valves ground to suit, ensuring a steam-tight joint without hand fitting.

Frame.—The crosshead guides and main bearing parts of the frame are to be cast in one piece and the frame is to rest on the foundation for practically its whole length.

Governor.—The governor is to have control of the cut-off on both high and low pressure cylinders, and when driving alternating current generators in parallel, the momentary variation caused by throwing on or off the entire rated load shall not exceed three per cent. of the mean speed of the engine.

Crank and Crosshead Pins.—These pins are to be of steel and are to be case-hardened and ground to a true surface, and are to be inserted in the crank at perfect right angles in all directions to the centre line of the engine.

Oiling System.—The engine shall be provided with an automatic oiling system which shall feed oil under pressure to all bearings.

TYPICAL EUROPEAN LOW HEAD HYDRO-ELECTRIC POWER PLANTS.

CHARLES H. MITCHELL, C.E.

M. Can. Soc. C. E., M. Am. Soc. C. E., A. M. Inst. C. E., A. Am. Inst. E. E.

In the following it is the writer's desire to describe, in a very short manner, the salient features of three typical European Hydro-electric power developments, operating under low heads. For this purpose a plant is selected in each of the three representative countries, France, Italy and Switzerland.

It is probably not necessary to offer any introductory remarks regarding such engineering works, as it is well known that, in many features connected with Hydro-electric power development, European engineers lead, both in design and construction. Especially in the mechanical and hydraulic branches was this subject reduced to a science in the region of the Alps long before an equal progress was made in America. This was due to the necessities of those countries poor in coal or other fuel and rich in water powers.

Of late years, engineers on this side of the Atlantic have learned to regard European practice in this branch as the leader, so to speak, much in the same manner as the fashions in London and Paris are watched by the sartorial designers.

The following descriptions were included in an illustrated address on this subject given by the writer before the Engineering Society in February, 1907.* The illustrations shown were obtained by personal visits to these plants during the year 1906.

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* These plants, along with numerous others in Central Europe, are described more at length by the writer in a series of articles in the "Canadian Engineer," which appeared during the year 1906.

LYONS INSTALLATION ON THE RIVER RHONE.

The city of Lyons with its population of half a million, is second in size, but first in industrial importance, among the provincial cities of France. This distinction is largely due to its geographic situation, since it is practically in the centre of the country, and is located at the confluence of two navigable rivers, the Rhone and the Soane; hence, secures for it a large provincial trade, and makes it an ideal distributing centre. The surrounding cities and towns contribute their share toward this activity; notably St. Etienne, with its steel works—the largest in France.

Lyons, as a user of power for manufacturing purposes, offered an attractive field for enterprise. The diverse character and limited extent of its respective manufactures calls for relatively small quantities of power, requiring a varied distribution and numerous units. The main demands for mixed power come from its silk, fancy goods, leather, wine, brewing and light metal establishments.

The Société des Forces Motrices du Rhone first undertook in 1894 the construction of a hydro-electric plant for the purpose of transmitting power to Lyons, a few miles distant, and thus became one of the pioneer European hydro-electric power producers. The site chosen for development was on the Rhone, a few miles above Lyons, and was such that high tension transmission was unnecessary. The result now is, that as in similar instances in America, a large industrial suburb, Ville-urbanne, has sprung up near the generating station, notable for its lack of chimneys and its uniformly neat appearance.

For a distance of about ten miles above the generating station, the Rhone flows through a very irregular bed, consisting of a network of rapids and small swift streams, among gravel islands, in a broad valley, having a total fall of about 35 feet. The main channel is canalized by the Government for shallow draft. The general scheme of the power development comprises a head canal from the Rhone above the rapids to a power house site, thence a tail race canal to an outlet in the Rhone below the rapids, a total distance of about 11 miles, the whole known locally as the "Canal de Jonage." This arrangement affords a working hydraulic head of about 38 feet. The amount of water available is limited by the natural conditions and the requirements of the Government to from 3,000 cubic ft. per second at low water, to 4,800 at high water.

The generating station has frequently been noticed in the technical journals during the past few years; it is not the intention in this article, therefore, to enter into elaborate details, but simply to set forth the engineering features of this notable installation. The building itself is about 475 feet long, and is built largely of concrete, trimmed with stone and tiles. The units are directly connected; of the vertical shaft type, 16 in number, each of about 1,250 net h.p., under normal conditions of the river; there are also 3 exciter units. Water is led to the turbines from separate bays on the upstream side of the station, each having its own screens and sluice gate. The latter is unique, as being in the nature of a cylindrical drum, 10 ft. in diameter, closing the top of a vertical inlet pipe. It is raised and lowered by a chain hoist worked from within the station shown on the right hand side of the interior view of same.

The units are arranged in line at about 27 ft. centres. The eight central units, four on each side of the central bay—which contains the exciter units and switchboards—are operated by Jonval turbines made by Escher Wyss & Company, of Zurich, the installation of which was completed about 1897. These are of a special type, having a three stage runner with downward discharge into a draft tube, and water fed to it through three separate and parallel distributors or guides at about 45 degrees; all fitted with cylinder gates. The thrust is provided for by a large disc or piston about 6 ft. diameter, attached to the shaft within, and at the top of the case. The closed chamber on the upper side of the piston is connected to the tail race. Regulation is secured by a special governor, consisting of a rotating disc and servo-motor actuating valves in conjunction with a high pressure oil pump, by which the gates of the turbine are operated. This turbine gives an efficiency of about 76 per cent. at full load, and the governor is said to regulate within a speed variation of 4 per cent. on a change of half load. The other eight main units, four at each end, were installed in 1902, also by Escher Wyss & Co., and are of the Francis type, having a double runner with central outward discharge, and are said to give an efficiency of about 83 per cent. It is to be noted that the latter type discharges water in the tail race with less air and commotion than does the Jonval.

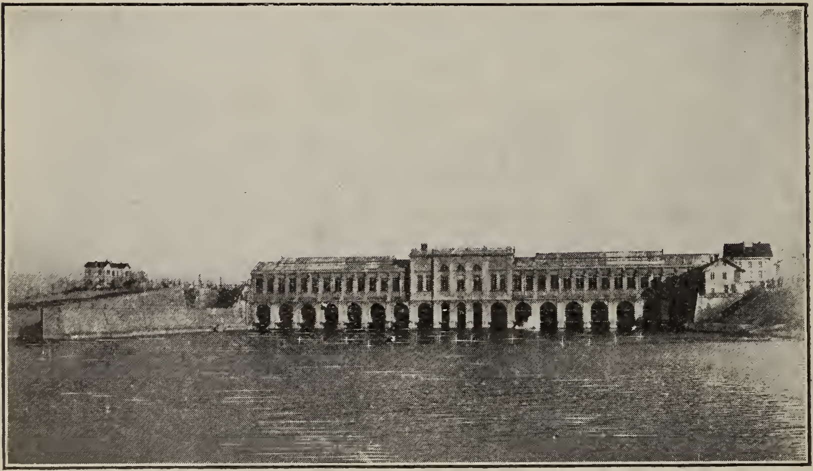


FIG. 1.—LYONS—GENERATING STATION ON THE RHONE.

The electrical apparatus is very simple for a station of such magnitude. The generators are wound for three phase, 50 cycles, and 3,500 volts, and revolve at 120 R.P.M. The exciters (3 separate turbine units) provide 170 K.W. each, and revolve at 250 R.P.M. All generators are run in parallel through a simple switchboard directly to the transmission and distribution lines without transformers. The electrical apparatus was built and installed by Brown Boveri & Company, of Baden, Switzerland.

While Lyons is in Southern Europe, freezing weather is frequently experienced. In the winter of 1904-05 the thermometer went at times as low as 5 degrees Fahr. above zero; on which occasions the station experienced trouble from frazil ice. This had the serious result of occasioning several days' shut down. It is a question whether this ice is formed in the upper river, in the foothills of the Alps, or immediately at the station; the company's engineer inclines to the latter opinion and has tried many artifices to obviate the trouble, but without success. At the time of the writer's visit, January 24th, 1906, the thermometer was down to about 15 degrees Fahr., and in anticipation of trouble, two 25 H.P. steam boilers on scows were supplying live steam at about 8 lbs. pressure to the covered forebays at the screens and sluice gates. To a Canadian in Southern France, in the heart of the silk country, this presented an interesting spectacle.

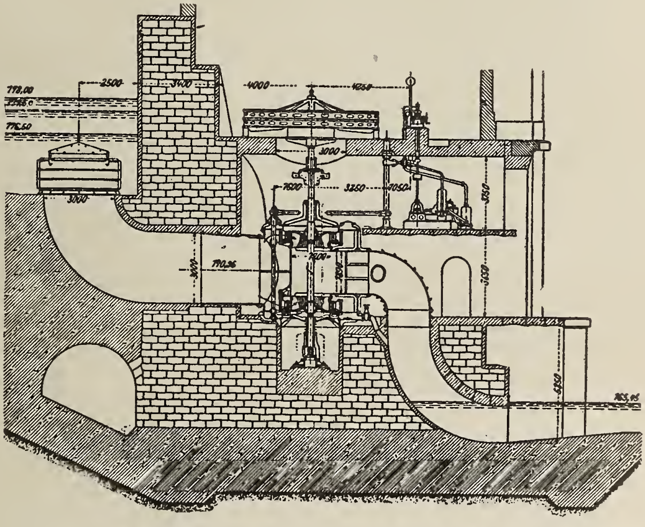


FIG. 2.—LYONS—SECTION THROUGH 1,500 H.P. FRANCIS TURBINE UNIT.

The power now in use amounts to about 14,000 H.P. at normal conditions. Of this, about 1,500 H.P. is traction load, 3,000 H.P. lighting load and the remainder mixed motor load. The tariff charged may prove interesting at this juncture for comparison with conditions in Ontario in view of the work of the Power Commission. Good quality steam coal at Lyons is about $4.25 per ton. The prices for motor power are as follows:—Up to 100 H.P. at 11½ cents per kilowatt hour; for over 100 H.P. at $34.00 per H.P. per year on a 12-hour basis, and $45.00 on a 24-hour basis. There is a sliding discount on the above prices as follows:—On a bill of $20.00 per month, 1 per cent.; on $50.00 per month, 2½ per cent.; on $100 per month, 5 per cent.; on $200 per month, 7½ per cent.; and on $300 per month, 10 per cent. For lighting, which the power company itself operates directly, the charges are as follows:—On meter system 13 cents per kilowatt hour for stores, hotels, cafes, etc.; 10 cents per kilowatt hour for houses. If on a flat basis the lighting rate is as follows:—For a 16 C.P. lamp, burning 750 hours, per year, $4.20; for 10 C.P., $3.75; for supplementary hours, add 6-10 cent for 16 C.P. and 4-10 cent for 10 C.P. for each hour. In the flat rate the bill is determined by a time meter.

TREZZO INSTALLATION NEAR MILAN.

That Milan is one of the most prosperous and enterprising of European cities is well known. It is the centre of the great plain of Lombardy, which for centuries has been famous for its wealth in agricultural products and dependent industries. The city has always been the commercial metropolis of Northern Italy, and is now the emporium of all Italy, just as Genoa is the national seaport.

To describe the industries of Milan would require a lengthy enumeration of nearly all branches of commerce and manufacture; and the long list would, without a doubt, represent a greater diversity of interests than any American city of like size, and even larger population. The proximity of Milan to the Alps on the north and availability of economical electric power from hydraulic plants situated within transmission distance of the city has had the natural result of stimulating industry and establishing numerous factories.

The first application of electrically transmitted power was, of course, to lighting and traction, and for this purpose the pioneer

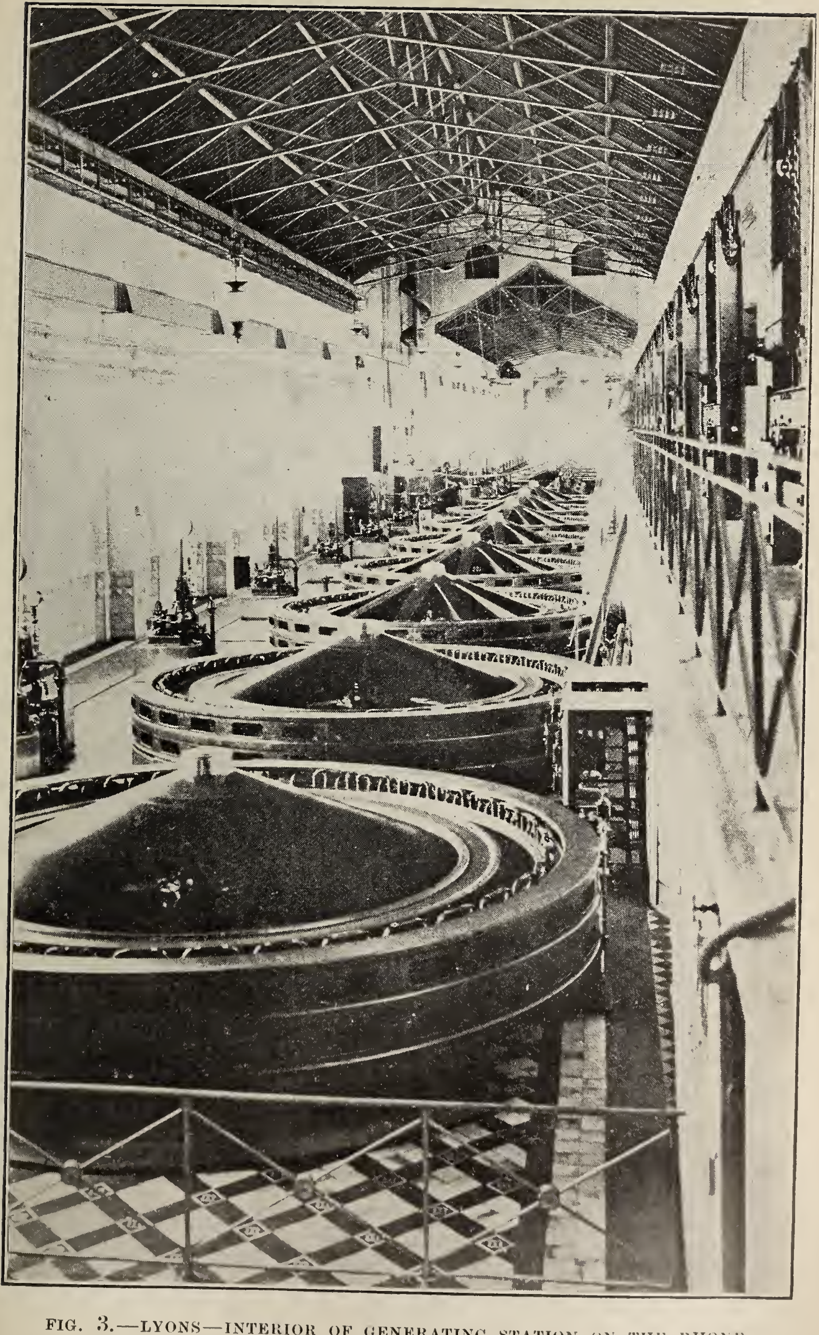


FIG. 3.—LYONS—INTERIOR OF GENERATING STATION ON THE RHONE.

company, "Societa Generale Italiana Edison di Elettricita," constructed and commenced operating a hydraulic plant at Paderno, on the Adda River, twenty-five miles north-east of the city. This was in 1898, but the same company had already a steam plant in Milan dating from 1883, with railway and lighting franchises. After the installation of the hydraulic plant, motor power for manufacturing purposes came gradually into great demand, with the result that this company not only extended its original hydraulic and auxiliary steam plants, but, with partially allied companies, has recently installed several other hydro-electric generating stations, with which the Paderno and steam stations run at times in parallel. These new stations are Zogno, 40 miles distant north-east, which commenced operation about January 1, 1905; Vigevano, 20 miles south-west, commenced operation January 15th, 1906, and Trezzo, 20 miles east, which commenced in the summer of 1906.

The Trezzo plant is selected in this article because of its very recent construction, and because of the new features introduced. The Adda River at this point (5 miles below the great Paderno station), makes a horseshoe bend around a rocky hill, and at the same time has a rapid fall. The power project consisted of damming the river at the crown of the bend, and placing a power house alongside the rock cliff, discharging the water from the tail races through tunnels, under the hill, to the river below. The low head thus obtained only 24 ft., required vertical shaft type of units, with low speeds and a corresponding large volume of water, with many units.

The construction of the dam was a very delicate operation, owing to the rise, and peculiar violence of the river after rains in the mountains, 30 miles distant. The foundations of the whole structure are of concrete, laid on the rock river bed, and, in the main portion, consist of large terraced courses of monolithic concrete, over which the water can discharge in high seasons. The upper part of this work consists of an adjustable crest formed by structural steel bents, provided with removable wooden sheeting and planking capable of raising the water to an elevation about 10 ft. higher than the permanent concrete crest, thus forming a huge flash board system.

Against the high cliff of the river, in the horseshoe, the power house was constructed, having its face parallel to the river flow opposite, yet almost square against the current on the approach to the curve; this arrangement provides ample water with minimum deflection, and at the same time produces a sweeping current to carry past debris, etc. The station shown in Fig. 4 is situated about 300 yards up stream from the sluice gates, and is a large and very handsome structure built entirely of stone. The stones are left rock face, but are hewn roughly to courses, and are obtained from the cliff alongside, which is formed of a peculiar cemented gravel, resembling a thoroughly mixed hard gravel concrete. The stones after slight dressing give a very pleasing effect, which many architects would strive hard to obtain in concrete by artificial means.

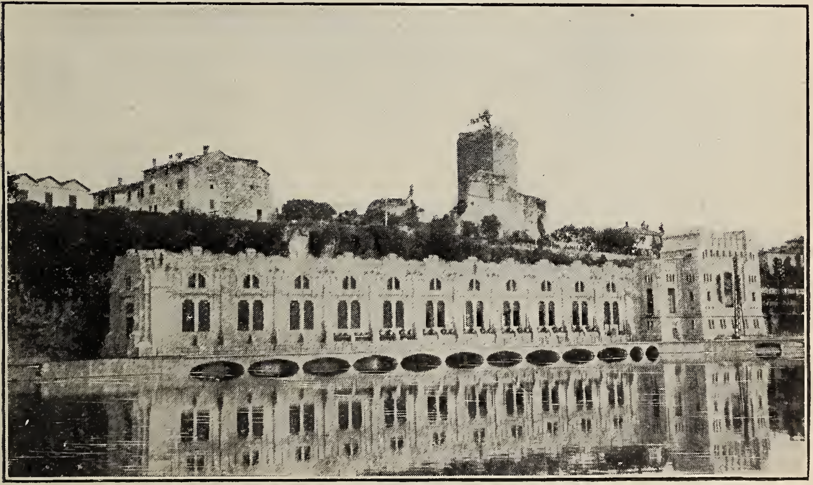


FIG. 4.—TREZZO—EXTERIOR OF GENERATING STATION.

It will be seen in the illustration that there are ten main water entrances, each 22 ft. wide, and two exciter inlets. These represent as many units, and the water in each, after passing screens and gates, enters a wheel pit with its vertical turbine, thence into the tail pit and common bay, about 300 x 60 ft., in the rear of the station. From this point the water is conveyed by means of two tunnels beneath the cliff to the lower river. For a distance of 150 ft. above the station and in continuation of the face of the water inlets, a series of 10 overflow weirs is arranged to take care of slight inequalities in the river level.

The vertical turbines are Francis type, each of 1,500 H.P. capacity at 105 R.P.M.; the first six and the two exciter units are by Riva Monneret & Company, and the seventh is by Escher, Wyss & Company, of Zurich. Considerable use has been made of re-inforcing steel in the concrete foundations and settings of these machines. The governors are connected by two stems to the gates. In general arrangement (see Fig. 6), the power units are similar to those at Lyons already described. The generators are of 3-phase revolving field type, two at 50 cycles, and the remainder at 42 cycles, and are built by Gadda & Company, Milan.

In the arrangement of switches, transformers, arresters, instrument boards, control, etc., this station is, if possible, more complete and roomy than that at Vigevano, and the whole large wing at the end of the station is occupied by this apparatus. The distant control apparatus is, in itself, a very perfect arrangement, permitting complete operation from table switchboard to isolated apparatus in different compartments of switch and transformer rooms.

Four transmission circuits, three to Milan and one to Bergamo, are now in operation at 13,000 volts, carried on structural steel towers known as the "Elastic" type. The function of these towers is that while rigid at right angles they will oscillate slightly in the direction of the line, creeping of the cables being prevented by guying at intervals. These towers are 40 ft. high above ground, built with two legs (channel section) 7 ft. apart, and each leg set in concrete 5 ft. deep; the top of each leg member carries two circuits. Insulators on these lines are of the Paderno type, but are being partially replaced with a new design recently patented by Signor Semenza, consulting engineer of the company. This is a radical departure, but most simple, with qualities of insulation which are obvious. The design, which can be better illustrated (Fig. 5) than described, consists of the lower portion of a simple Paderno insulator, provided with a threaded top and side groove in which the wire passes: over the top is screwed an "umbrella" made of terra cotta about 12 in. in diameter, having a small watershed arranged on each side above the wire. It is interesting to know that in the breakdown tests on an insulator designed for 30,000 volts, the ratio between wet and dry conditions is nearly unity, viz.: 122,000 volts for dry and 110,000 volts for wet. A feature of this new type is its small cost, the expensive, large upper part of the usual porcelain insulator being replaced by a simple, easily formed piece of terra cotta or other cheap material. As jokingly pointed out by Sig. Semenza, a new umbrella is, in this case, cheaper than an extra petticoat.

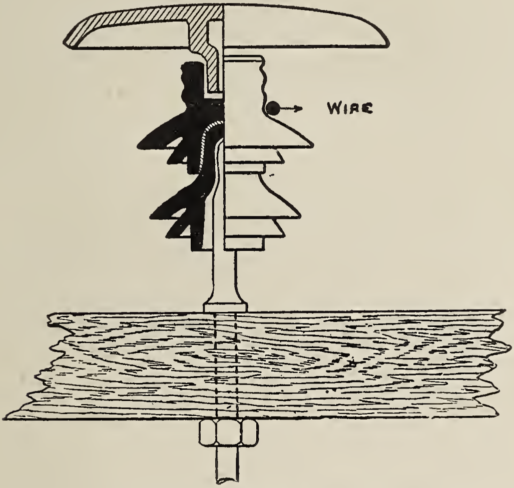


FIG. 5.—SEMENZA UMBRELLA TYPE OF INSULATOR.

THE BEZNAU PLANT IN SWITZERLAND.

One of the most interesting low-head plants in Switzerland today is that situated on the Aare River, near Baden, known as the

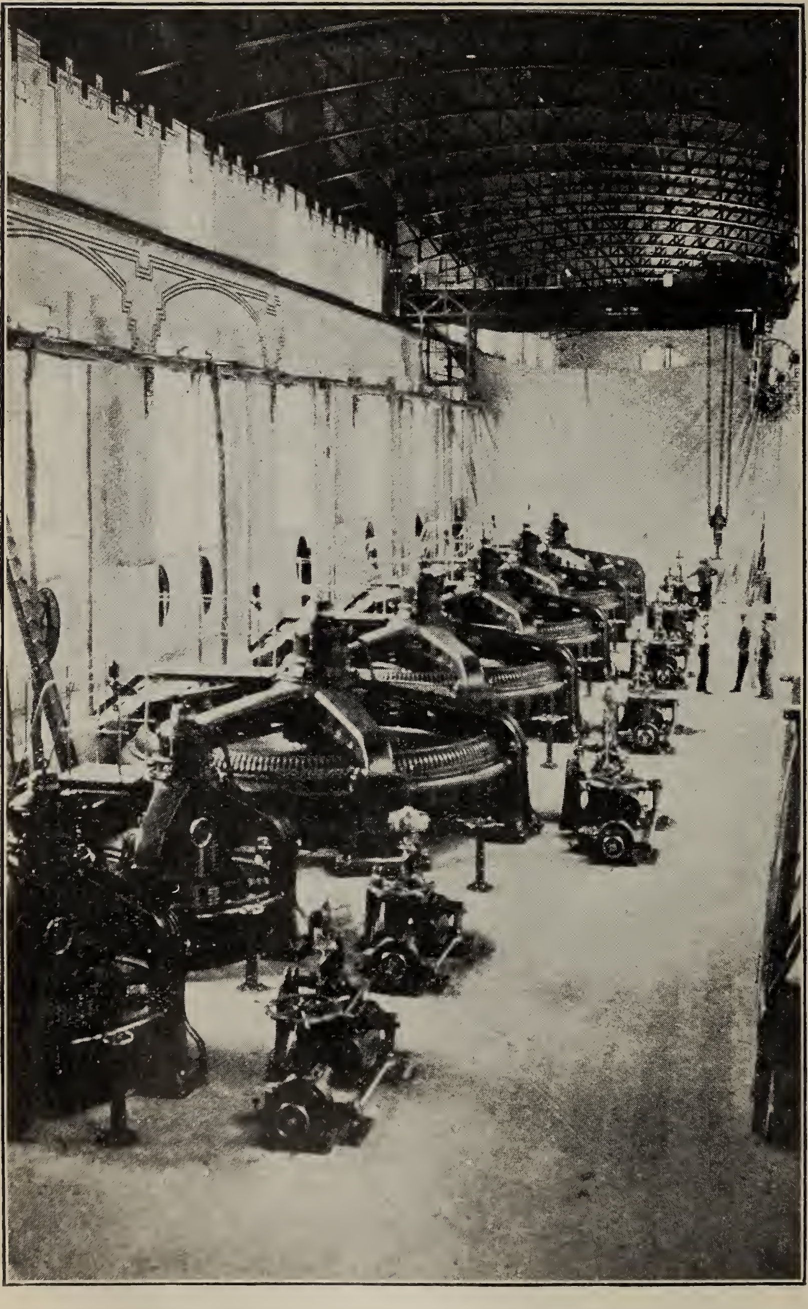


FIG. 6.—TREZZO—INTERIOR OF STATION.

Beznau Station. In it are constituted all the most recent improvements in the application of the water to the wheels, and in the wheels themselves are embodied the rsults of the experience of the past ten years, with plants operating low-heads with large variations. This plant was completed and put into operation in 1904, and was quickly loaded up with consumers in the surrounding country.

The water is obtained by cutting across a bend in the river with a canal about three-quarters of a mile long, and the generating station is placed across the lower end. A removable series of screens is provided, and also commodious spillways, although all ice and debris is deflected at the headworks. The generating station below the floor line is built of concrete, the superstructure being of stone.

The available fall varies between 10 and 15 feet, and, owing to this variation, the vertical turbine units consist of three runners 7 ft. 6 in. diameter. One pair of runners is at the bottom, right and left, and the third above, discharging downwards into the draft chamber of the upper runner of the pair, see Fig. 8. At a medium head of 13 ft. 1,000 H.P. is obtained on each unit at 67 R.P.M., using 890 sec. ft. of water. The whole unit is supported by hydraulic pressure beneath a disc, so as to reduce the weight on the step bearing, and the small inequalities of this are further balanced by oil pressure from special pumps.

Regulation is secured by an oil pressure governor geared to the main shaft, standing on the station floor, which is attached to the gate shaft. Links from the latter are connected up to the gate rings surrounding the distributor of each runner: to the gate rings are linked the swivel gates, which, by rotating the ring, open and close on the fixed vanes of the distributor, thus admitting water as required to the runners. The turbines are built by Theodor Bell & Co., of Kriens, near Lucerne.

The power secured in these units varies between 7,000 and 11,000 H.P. for the whole installation of nine units.

The generators are of the umbrella revolving field type, 800 K. W. each, three-phase, wound to 8,000 volts at 50 cycles, and were

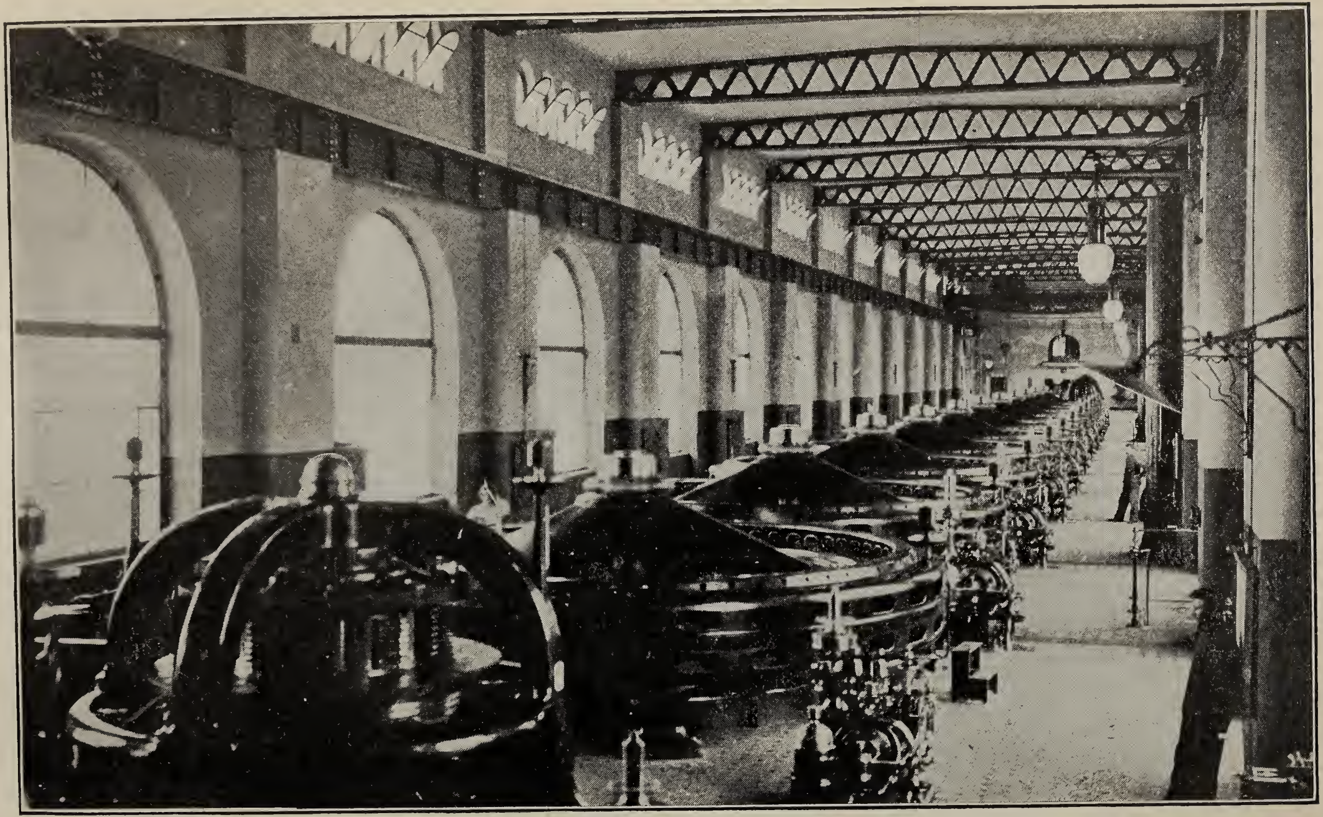


FIG. 7.—BEZNAU—INTERIOR OF GENERATING STATION.

built by Brown, Boveri & Co., of Baden. Local distribution is at the generating voltage, while long distance is at 25,000 volts up to 20 miles. The latter voltage was the highest in transmission operation in Switzerland at the end of 1905. The total length of transmission lines of this plant in 1905 was 70 miles, the number of localities served was 61, the population 250,000, the number of transformers 60, and stations 31, while the average power of motors served was 100 K. W., in which respect this plant stands third in the country.

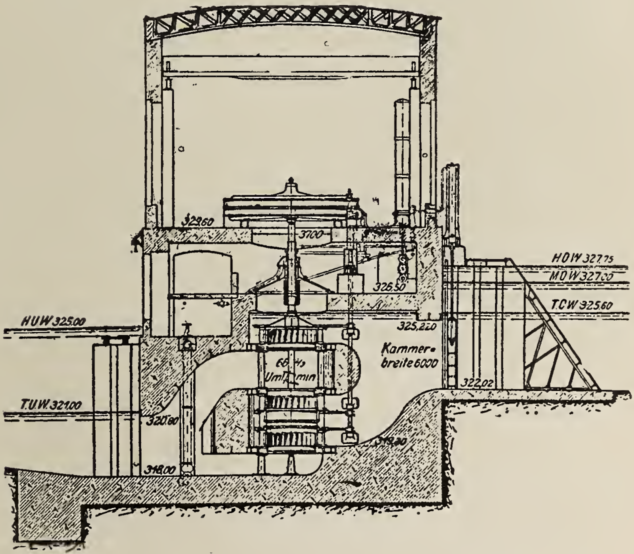


FIG. 8.—BEZNAU—SECTION THROUGH UNIT.

Prices of power are generally as follows: For lighting 16 C.P. lamps, $4 each per year, continuous service. For motors on 10-hour basis flat rate, 1 H.P. at $43; 10 H. P. at $39; 50 H.P. at $34, and 100 H.P. at $32. For 24-hour basis, 1 H.P. at $56; 10 H.P. at $49; 50 H.P. at $44, and 100 H.P. at $41.

MODERN STEEL BUILDINGS.

JOHN M. EWEN, M. AM. SOC. C.E.

I shall speak to you this afternoon about modern steel buildings and also about the modern methods of business organization which are necessary to the rapid and efficient construction of such buildings.

The first big building in which the idea of a steel frame was used to any extent was the Home Insurance Building in Chicago. This building was erected in 1883. Only 24 years have passed since that time. You can see therefore that the whole revolution in modern building construction has been condensed into a space of less than a quarter of a century.

The principle first embodied in that building has completely changed the character of big building construction. But there has been a change not only in the buildings themselves, but in the methods of organizing the architects, the engineers, the contractors, and the artisans, who construct the buildings. Fifteen years ago the erection of an eight or ten-storey building was considered a good year's work. To-day a building twenty-five or thirty storeys high can be erected within that same length of time. This change is due to improvements in methods of work. The modern construction engineer, engaged in the erection of big buildings, has a business organization which differs from the business organizations of 25 years ago, almost as much as the steel building itself differs from its solid-masonry predecessors.

As an example of the rapidity with which a modern engineering force can work, we may take the Sears-Roebuck plant on the west side of Chicago. This plant consists of four large buildings. The largest in the group is ten storeys high, four hundred feet wide and sixteen hundred feet long. The total cost of the plant, including all buildings, was more than four million dollars. Yet the whole job was done in eight months. In other words, building construction has not only been changed but accelerated. It is not only different in materials but different in methods. It has not only more steel but more speed.

And, by the way, the speed is just as important as the steel. When an old building is torn down in the heart of a great city, the owner loses his rents from the time when the old tenants are turned out to the time when the elevators begin to carry the new tenants to their new offices. Can the engineer constructor have that new building ready in ten months, or will it take him eleven? The difference of one month is important. There are office buildings which have a monthly rental roll of fifty thousand dollars. That sum represents to the owner the difference between an engineer constructor who can put up his building in ten months and the engineer constructor who cannot do it under eleven. It is therefore absolutely necessary that the modern engineering force should be able to do its work, not only with the utmost care, but with the utmost rapidity. This means that the best type of engineer constructor, in order to be able to handle big building operations, must have in his own office, or else closely associated with him, all the different kinds of talent which go into the construction of the modern skyscraper. In other words, the modern engineer constructor is not an individual. He is an organization.

You will be able to see what I mean if I just name the different kinds of trained men who ought to be included in an engineering force competent to perform a modern building operation with the smallest possible loss of time. An architect; a civil engineer; an electrical engineer; a mechanical engineer; a structural engineer; a sanitary engineer; a fire protection engineer; a purchasing agent; a construction superintendent; an operating engineer; an accountant. For the best work, it is no longer advisable to have all these men in separate offices of their own and to call them in from time to time in an advisory capacity to superintend their particular part of the work. It is better to bring them into what is, in effect, a single organization. They must work like the players in a football game, not as individuals but as a team. And they must have a captain whom they all trust and whom they all obey. He is responsible for every play in the whole game. He directs every movement. But he must have men under him who know their own specialties just as the left tackle in a football team knows how to be a left tackle, or the half-back knows how to be a half-back. The captain can then send that team down the field and have it under complete control and know what every man is doing every second. The difference between the old-style football of fifty years ago, when the players roamed all over the field very much at their own sweet will, and the modern organized football, in which the whole team is under perfect control, and moves like one man, is the difference between the scattered individuals who used to collaborate in the construction of a building fifty years ago, and the modern compact engineering force which brings all those individuals together in one team and which can calculate, almost to a day, the exact time which it will consume in getting a certain piece of work done.

Let us begin now at the beginning and see what happens from the time when a man decides that he wants a new building to the time when that building is handed over to him, ready to be used. We will suppose that our man comes to the office of an engineer constructor of the kind we have been talking about. He explains that he has an old building which will have to be torn down and that he wants to replace it with a modern office building on which he is willing to spend a certain amount of money. He naturally wants as much done with that money as possible. The engineer constructor now proceeds to make a prophecy of that new building, complete in every detail. There are men in the office who can estimate the cost of every particular kind of thing that will be needed. Each man can make a pretty fairly accurate forecast of the expense that will be connected with that feature of the building in which he is particularly interested. The advantage of such a careful estimate of prospective cost is manifest. The owner of the building then knows exactly what kind of building he can afford and just about how much money he will have to spend. This is an advantage which in former days it was sometimes very difficult to secure.

There have been times when an architect would draw plans that were attractive to the owner and that promised a building of a kind that he would enjoy possessing. These plans having been all made and the dimensions and decorations of the building having been decided upon, the different contracts for steel, brick, granite, etc., would be awarded, one after the other. Everything would go on pretty well till one day the architect would come to the owner and say: "Well, I am sorry, but that building will cost three hundred thousand dollars more than we thought it would." In fact, there is one architect who always introduces some humor into the situation and says: "Well, you'd better go out and take half a million dollars more away from somebody. We'll need it before we get through." These things are often quite annoying to the owner. They are avoided when architects and engineers work out the plans together and when the architects can compare their ideas of what would be desirable with the ideas of the engineers as to what is financially possible.

The exactness with which a financial estimate can be made was seen in the case of the new County Building for the City of Chicago. When the plans for that building were being drawn up it was known that there was a certain appropriation for it, and every effort was made to draw the plans in such a way as to make allowance for every possible detail and still keep within the appropriation. Finally after the estimate had been made, and after the specifications for the steel contract, the granite contract and all the other contracts had been printed, showing just what was wanted, the contractors were all asked to come in and bid on the work. When all the bids were in, and when all the contracts had been awarded, it was found that the actual contract cost was only fifty thousand dollars away from the estimate of five million dollars that had been made before any of the contractors had named their price. When building can be done in this way, it saves the nerves of the owner. If the estimate is too high, he can cut his plans and try to satisfy himself with a more modest building. If the estimate is satisfactory he can order the engineer constructor to go ahead.

The engineer constructor must now plan his campaign like a general. He must not allow a moment to be lost. And in order to avoid the loss of a moment he must lay out a complete time schedule for his building to follow. The civilian is likely to imagine that the general of an army simply starts out in the direction of the enemy and wanders along till he finds him. In the same way the man who is not familiar with engineering practice is likely to think that the engineer simply starts building and keeps on building till some day he gets through. As a matter of fact the first thing that an engineer does when he begins a building is to calculate practically the exact day at which that building will reach each successive stage in its construction. In other words, he writes a diary for that building, but he writes it beforehand instead of afterwards. This table of dates shows the exact stage at which the building is scheduled to arrive on the days mentioned. It gives everybody connected with the construction of the building his cue for coming on and going off. It is the running-time for the construction engineer just as the time-table of a railway is the running-time for the locomotive engineer.

As we go on now with our building we will suppose that the owner wants a building with a steel frame. It is a mistake, however, to suppose that a steel frame is absolutely essential to the construction of a high building. There is one reason, among others, why a solid-masonry building would be unsatisfactory to the modern owner. The walls of such a building have to be extremely thick. They must be immensely broad and strong in order to support the weight of the structure. The consequence is that a great deal of space that might be used for offices has to be used for walls. If such a building had a steel frame, the walls would be so much thinner that the floor-space, capable of being devoted to offices, would be increased by twenty-five per cent. Obviously it is to the advantage of the owner to build with steel. The old County Building, Chicago, furnished us with an illustration. The walls of this building were twenty feet thick at the first floor. The walls of the new building, which is steel construction, at the first floor, are only three feet thick. The saving in floor space is obvious.

There is also another reason for preferring steel-frame buildings of the most modern construction to buildings of the old type. This second reason is their superior safety.

Masonry by itself, or slightly and imperfectly supported, cannot sustain a severe shock or jar of the kind given by an earthquake. This was demonstrated in the San Francisco disaster, where buildings of the old type tumbled down, while the steel frames of the modern buildings were practically intact after the earthquake and after the fire. The reason is to be found in the method of construction. The steel columns and beams were so firmly fastened together with rivets and so strongly braced that the whole frame-work was practically as stiff and rigid as a steel cage. The masonry walls were carried on the outside steel beams and were tied to those beams with strong iron anchors at every floor. Finally another precaution was added. Under the window sills of each storey a flat band of iron, about five inches wide, and a quarter of an inch thick, was laid in the masonry and carried all the way around the whole building. This band of iron is riveted to the columns as it passes them and acts as a horizontal support for the masonry. The whole building could actually be tipped several feet out of a vertical line without endangering its integrity.

For reasons of safety, therefore, as well as the desire to get more floor-pace, the owner of the prospective office building is likely to want a steel frame.

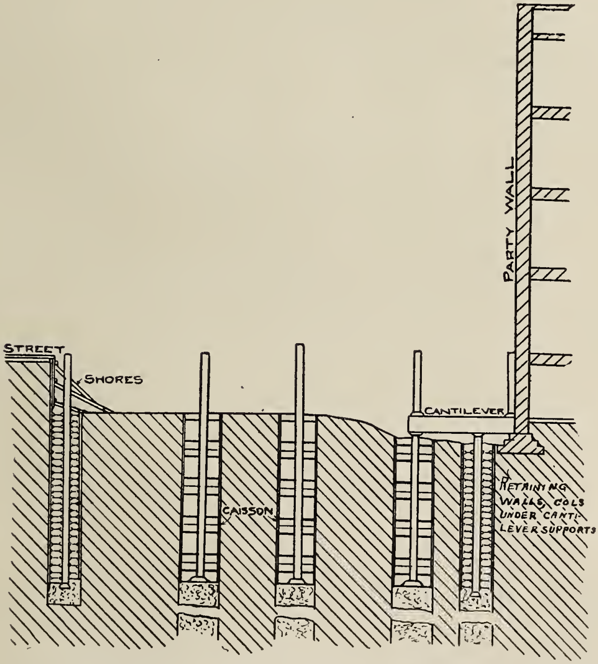
The plans made by the engineering force for the new building will now show exactly where every piece of material is to be put. When the building is completed the thing that seems remarkable is its size. When it is being built the thing that seems remarkable is its infinite number of small details. All these details are represented in the plans. These plans, specifications, blue prints and documents of all sorts multiply at an astonishing rate. If they were all brought together in the case of a building like the Cook County Building in Chicago, and put on a scale and weighed, they would tip the beam at something like thirty tons. At this stage it is not the big work of engineering practice, but the small work, that attracts the eye. On the tables in the architects' and engineers' offices, where the plans are kept, they give a complete picture of the building which has not yet been begun. The smallest piece of steel that goes into a column up on the fifteenth floor of the building is already in its place, its exact place on the plans. The building exists completely in imagination before a single stone has been placed in the foundations.

The engineer constructor, if he is in complete charge of the building, will now proceed to let the contract for tearing down the old building. The contractor who does the job of taking it away will make good use of all the usable materials it contains. He will have a big yard or warehouse in which the steel, the iron, the stone, the bricks and the other materials will be sorted out and heaped up and sold to people who can use them. In some cases the stone from the old building is crushed on the spot and mixed with sand and cement to make concrete to be used in the new building.

While the old building is being battered down and carted away, other contracts are being let. It was formerly customary to follow up the demolition of the old building immediately with the excavation of the space for the foundations and basements of the new building. It is now feasible, however, to do the foundation work before doing the excavating. This seems like a contradiction in ideas. But the process is comparatively simple. And it saves a great deal of trouble.

If you follow the old method and dig the big hole in the ground before you lay your foundations you have to support the sides of this hole with long, strong timbers, and you are constantly worried by the fear that some of these timbers may slip and break and that the building next door or the pavement of the street may feel the jar and may be more or less seriously damaged.

Suppose, for instance, that the building has been torn down, and that you have proceeded to make a large excavation. You can readily see that it is necessary to take great precautions in order to protect surrounding property from injury. Instead of taking this



OLD BUILDING DOWN ; WALLS IN ; CAISSONS COMPLETED AND COLUMNS SET.

risk, you may, if you please, allow almost all the dirt to remain in place and get your foundations all in before you dislodge it.

You begin by digging a trench along the sides of your lot. The sides of this trench you support with horizontal planks which are braced apart by screw braces. Finally, when the trench has reached the desired depth of your lowest basement, you put in a concrete base at the bottom of it and instal vertical steel beams all the way up the middle of it from bottom to top and brace these beams with jack-screws, set between them and the planks which still form the sides of the trench. The pressure from the street and from the earth and the buildings surrounding your lot is now transmitted across the trench through the planks and the jack-screws, and the steel beams, and is now successfully resisted by the big core of earth which you have left still occupying the whole centre of your lot.

You are now ready to dig the wells for your caisson foundations. At various spots on your lot, that is, wherever you intend to have a steel column for the support of your building, you begin to make a round hole. The rest of the earth on the lot remains unexcavated, just as it was. All the excavating you now do is simply for holes which will afterwards be filled with concrete and used to support your steel columns.

The depth to which you dig these holes will depend upon the size of the building and the character of the soil. In Chicago you may choose between two different levels. One is hard pan. The other is bed rock. The first is found about sixty feet below the surface in the down-town district. The second is not reached till you have gone down one hundred and ten feet. In the case of a large building it is usually advisable to go all the way down to the second level.

As these wells are dug they are lined with heavy strips of wood, called lagging, and they are further protected by the insertion of metal rings which keep everything steady and transmit all pressure from every side. The digging is usually done by hand, with shovel and pick, and is good, hard work, especially when the laborers get down toward bed rock. Recently, in a caisson well six feet in diameter, two men worked for eight hours and made only eight inches of progress.

When the wells have finally reached the requisite depth, they are filled with concrete to the level at which the bases of the columns are to be set. The bottom of the well has previously been somewhat enlarged, or "belled out," so as to transmit the weight of its load over a large area. The rest of the well is of the same diameter throughout.

These columns of concrete are commonly called caissons, though they do not, strictly speaking, deserve that name. The word caisson, in engineering practice, really refers to a foundation which is made under water by men who are working in a chamber filled with compressed air. Caisson disease is the disease which men get through breathing the compressed air in a chamber of that kind. Our caisson wells in Chicago are not built under compressed air at all. They are simply dug with a shovel and pick, just in the same way in which any ordinary excavation is made.

General William Sooy Smith, a famous American engineer, recommended the use of what we now call caisson foundations at the time when the Masonic Temple was built twenty years ago. At that time the idea was not thought feasible. Later, however, it was tried in the Stock Exchange Building of Chicago, and it soon began to win its way into favor.

Of course, the other kind of foundation is still used. In many cases long piles are driven down into the ground and the building rests on them. Care must be taken, however, to see that the heads of the piles are driven down below the water level. Otherwise, they will rot.

In other cases, the foundations consist of what might be called rafts of steel beams, placed closely together, and set in concrete. These raft foundations, or floating foundations, support the columns which in turn support the floors.

One disadvantage about pile foundations and about raft foundations is that they settle when the weight of the building is imposed upon them. It is therefore customary in such cases to build the first floor of the building several inches higher than it ought to be, and then wait for the whole structure to settle down to its proper level. In some places in the down-town district of Chicago, you will notice that the sidewalk slopes from the building to the street.

This means that the building did not settle as much as its builders thought it would. In other cases the sidewalk slopes the other way. That means that the building was made heavier than was expected and that it settled too much, so that the slope of the sidewalk is toward the building from the street.

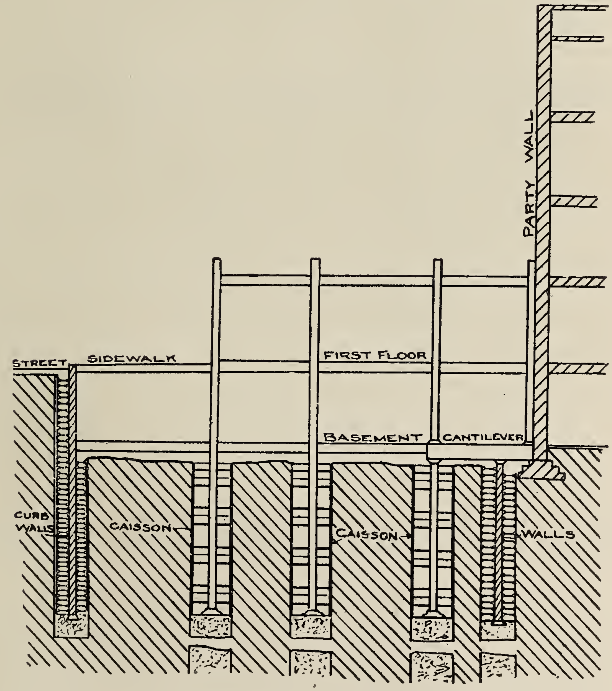
Another disadvantage about raft foundations is that they take up a great deal of space. Sometimes they even extend over into the next lot under the adjoining building.

A case of this kind was once carried to the Supreme Court. It was a dispute between Mr. Field and Mr. Leiter. Mr. Field won. The Court decided that he had the right to extend his foundations into Mr. Leiter's property. I was connected with the controversy in the interests of Mr. Field, and it became my duty to go to Mr. Leiter with the necessary drawings and show him exactly what we intended to do. There was to be a floating foundation 26 feet wide, thrusting itself under the party wall and resting half on Mr. Field's property and half on Mr. Leiter's.

Mr. Leiter studied the drawings carefully for a long time and then said, "Well, what shall I do if my neighbor on the other side should wish to perform the same kind of building operations as Mr. Field? He would want a similar foundation of the same width, 26 feet, and would naturally want thirteen feet of my land. This would make 26 feet of land that I would be obliged to furnish. Now, as I have only 25 feet, do I not run the risk of being sued for not having land enough to accommodate my neighbors?"

Let us now go back to our own building. The wrecking contractor has removed the old building. The foundation contractor has dug the caisson wells and has filled them with concrete. We now have our concrete columns on which to rest our steel columns, and we are ready to go ahead with the erection of the building.

Meanwhile the core of earth where the basements will be is still in place. We have saved a good deal of time by letting it stay there and by getting the caisson wells dug and filled first. If we had spent our time excavating we should not be able to begin on the steel work till late in the season, and then the cold weather would come on and the men would be subjected to hardships and the work would be delayed. Now, however, we shall be able to get all the outside work done during good weather, and by the time winter comes we shall have the shell of the building completed and we shall be able to turn some steam on while the plasterers and decorators are finishing the interior.

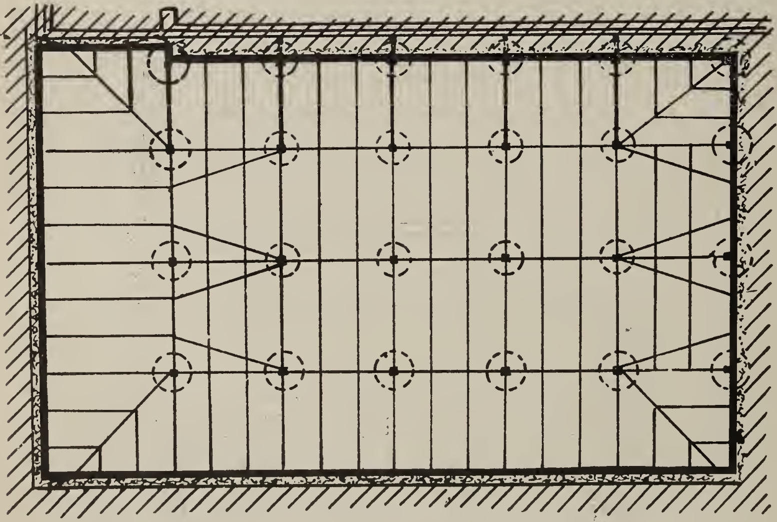


FIRST FLOOR AND BASEMENT FLOOR BEAMS IN ; EXCAVATION IN PROGRESS ; SUPERSTRUCTURE GOING UP.

Meanwhile we can do our excavating at our leisure, and we can go as far down as we please and put in as many basements as we desire.

It is coming to be customary to go forty feet downward in Chicago and to have three or four basements.

Deep basements have become very desirable in Chicago ever since the freight tunnel was built. This tunnel is forty feet below the street level. It is about seven feet in diameter and fifty miles long. It runs underneath practically all the streets of the downtown district, and it extends south to about Archer Avenue, west to about Halsted Street and north to about Chicago Avenue. It is designed to carry coal and merchandise and mail and express matter and anything else that can be transported in a bore of this diameter. To a considerable extent it is intended to relieve the congestion of teams on the streets above.



PLAN OF FLOOR BEAMS AS USED IN BASEMENTS.

In order to get down to the tunnel a building must have at least a third basement. Then it can receive its coal and get rid of its ashes, and do a lot of other work without cluttering up its sidewalks or its backdoors.

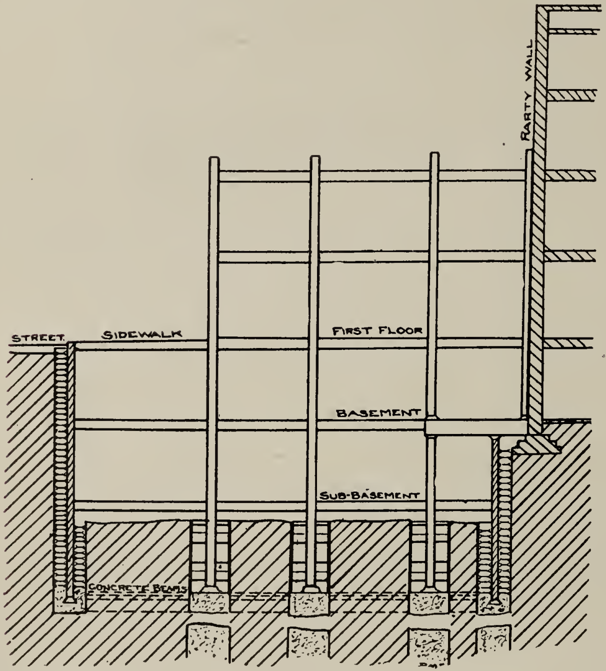
Altogether aside, however, from the advantages connected with a freight tunnel, it seems likely that the buildings of the future will have a great many basements. Land is so valuable in the heart of a great city that as we have been forced to go upward instead of spreading out, so we shall also be forced to go downward.

Using the methods we have already described, it would be perfectly feasible to construct a building with eight of its storeys underground. Such a building could be lighted by means of an interior court, extending all the way from the top of the building to the bottom of the lowest underground storey, if desired. From the engineering standpoint, there is practically no limit to the height or depth of a building. That is, of course, within reason. When you have caisson foundations, resting on bed rock, you have a basis on which you can construct twenty, thirty, fifty or sixty storeys without danger. The real limit is the financial willingness of the owner to pay for the expense of carrying on building operations at so great a height, and the personal willingness of the tenant to put in his time travelling from the fiftieth storey of one building to the fiftieth storey of another. The speed of the elevator service here becomes an important consideration. Such matters, however, are not directly connected with the actual feasibility of erecting high structures. Such structures can be built. And they can also be extended as far downward into the earth as is financially desirable.

Already there have been successful experiments in this direction. The Criterion Theatre in London is an underground theatre. The floor of the Criterion Restaurant forms its ceiling. The theatre is entirely underneath the restaurant, and the restaurant is at the street level. This is an extreme case. But it might frequently be desirable to build a theatre with its first balcony at the street level. One advantage of this plan would be that in case of fire the people in the second balcony would have a better chance to get out. They would be one storey nearer the ground.

Let us now return once more to our new building. While the basements are being excavated, the steel contractor is getting his columns erected and is starting the building on its upward course.

Meanwhile the other contracts have most of them been awarded. The brick, granite, the terra cotta, the ornamental iron, the elevators, the boilers, the electric wiring, the rubber mats, everything goes under contract. In quarries and in foundries and in factories the materials that are to go into our buildings are being dug and shaped and burned and rolled and pressed and stamped and tested and prepared for shipment. In addition to the engineering plans we now have shop plans, which go to the places where the materials are being made ready. Each piece of steel or iron or granite or terra cotta arrives clearly marked or numbered so that the workmen will know just where to put it. These workmen are employed by the contractors. The contractors have foremen who are in direct charge of the work. It is the business of the engineer-constructor to watch the contractors and their foremen and their workmen, and to see that they work harmoniously, and that they finish their part of the job on schedule time. The engineer-constructor tells them on what day they are each of them to begin, and on what day they are each of them to finish. He provides them with a schedule showing at just



SUB-BASEMENT BEAMS ALL IN ; STEEL OR CONCRETE BEAMS BETWEEN SIDE WALLS IN CELLAR.

what stage of progress they ought to arrive on certain successive days. The engineer-constructor therefore has his representatives on the site of the building every day. He is responsible to the owner for the accomplishment of the work and the owner deals with the contractors through him.

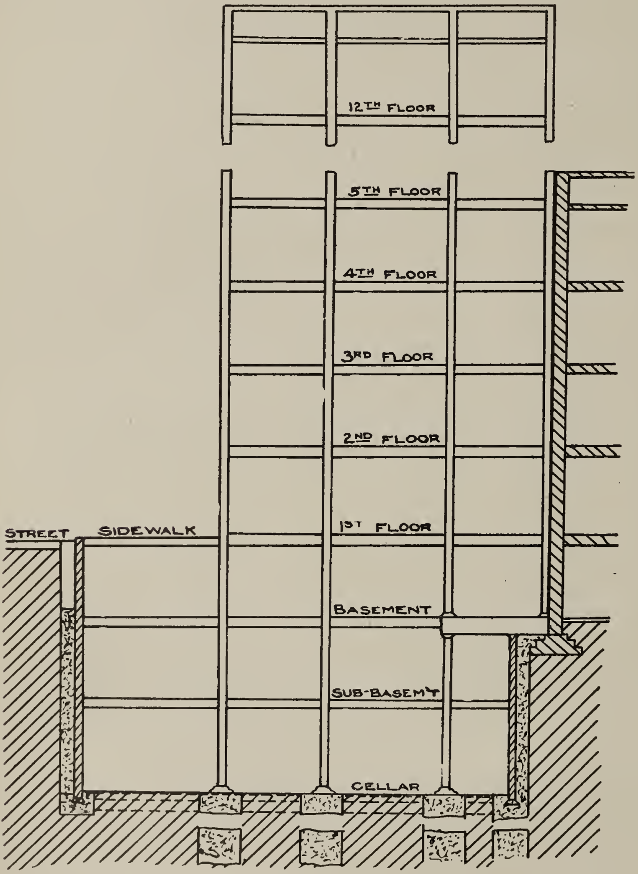
In speaking of the engineer-constructor in this way, we are assuming that both the architect of the building and the consulting engineer are in the same business organization or that they work together as a unit. If, however, the consulting engineer and the architect come from separate offices, then both of them keep representatives on the job and frequently visit it in person. Whether they are personally associated in the same firm or not, they after all represent the same idea. That is, they furnish the technical skill and knowledge through which the owner works in paying his money to the contractors. The contractors do the work of erection and are paid fixed sums for their labor and material. The engineer-constructor is usually paid a certain percentage on the total cost of the work. There are other financial methods under which buildings are constructed, but this is a quite usual one.

As the steel columns are going up it should be noticed that each one of them consists of a large number of different pieces of steel, all soundly riveted together.

Piece by piece, then, the columns rise toward the required height of the building. As they go up, the contractor erects steel girders between them at the floor levels and then erects steel beams between the girders. The floors therefore will be supported by the beams and girders; the beams and girders will be supported by the steel columns; the steel columns will be supported by the concrete caisson columns; and the concrete caisson columns will be supported by bed-rock. A building of this kind, carefully erected, is about the safest kind of building ever devised.

Right next to the steel comes the terra cotta or concrete fire-proofing. Each column in a fire-proof steel building is encased in terra cotta from top to bottom. This is called fire-proofing the steel.

Terra cotta is a clay product that has been burned with exceptional thoroughness. It has come to have a large place in building operations. And it is used not only to encase the steel frame of the building, but also to form the arches of the floors and in a more refined state to cover and ornament the street elevations of the building.



STEEL FRAME COMPLETED.

As the terra cotta, piece by piece, begins to creep over the steel, the brick contractor and the stone contractor begin to follow.

The brick and stone for the walls of the building rest usually on the outside beams and girders, called lintels, of each storey. That is, the masonry of *each* storey is really a structure by itself. That is why it is possible to do the masonry work on an upper storey before the masonry work of a lower storey has been started. Brick, stone and terra cotta may all be used in the walls of modern steel buildings. But they are only a shell. The kernel is the steel frame.

While the steel columns are being fireproofed with terra cotta, and while the walls are being built, the floor arches begin to appear. These arches are built on the ordinary arch principle, with key-stones and subordinate pieces. They are sprung between the beams and girders at each floor level. They support the weight of the flooring itself.

This flooring, on which people will stand, may be made of wood or stone or marble or concrete, or any other suitable material. But it is not the real floor. It is just a coating. The real floor consists of the floor arches. The floor arches sustain the weight of the flooring and of the things and people on the flooring.

When the steel frame has been erected and fireproofed, when the walls have been built, when the floor arches have been sprung, it is clear that the big outlines of the building have been completed. But meanwhile everything else has begun. The staircases are going in. The elevators are being installed. The boilers are being moved into the basement. The woodwork of the doors and windows is being erected. Glass is being moved into place. All these things keep happening at the same time, and unless they are managed harmoniously the building will be delayed.

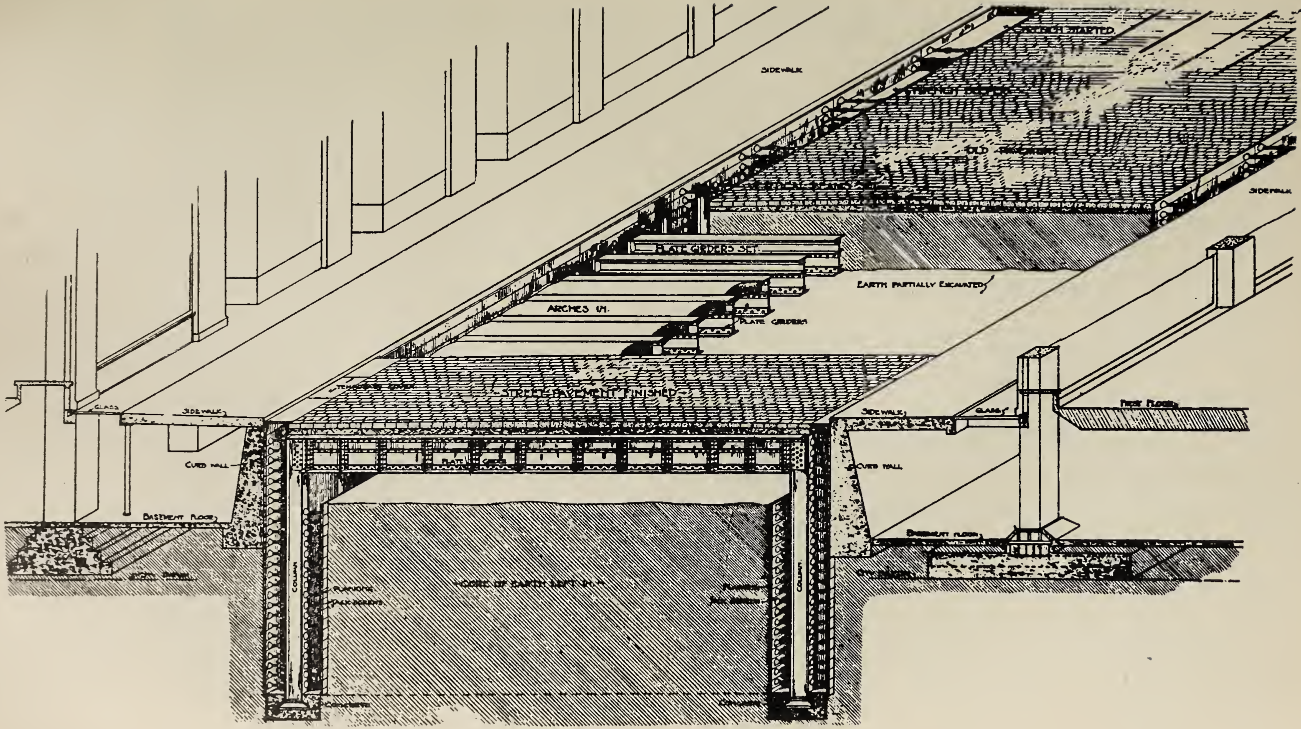
When the last tap of work has been done and when the building is ready to be handed over to the owner for occupancy, we can stand off and take a look at it. Six months, or twelve months, or eighteen months, depending upon the size of the building, have passed since the wreckers were let loose on the old structure. Since that time, the engineer in charge may have spent five million dollars on behalf of the owner. Of such a sum about $600,000 may have been spent on steel and about half a million each on brick and stone. In the new County Buildings, Chicago, there are 35,000 different pieces of steel besides 500,000 rivets. The steel pieces in that building, set end to end, would reach 250 miles. If the same weight which exists in these steel pieces were put into an iron bar a quarter of an inch in diameter, it would reach all the way around the world, with a thousand miles to spare. The granite in the County Buildings weighed more than 11,000 tons. Five hundred cars were needed to haul it from the quarries. The scope of such a structure, and its wealth of detail, are overpowering.

But let us take a look at its strictly architectural features.

Most modern steel buildings are erected for purely commercial purposes. The owner has land of a certain value. He puts up a building of a certain value. And he naturally wants to get the largest possible return on his investment. The architectural features of the building are therefore the features in which he economizes, except in so far as the public comes to demand a handsome building for business purposes. In some cases a big firm will erect a handsome building simply as an advertisement. In such cases the architect is freer to devote himself to the development of a beautiful structure. But the usual rule is that the building is strictly commercial, and that the owner is satisfied with such architectural beauty as will be sufficient to attract tenants. And perhaps it is more fortunate in some respects for the architect when the owner looks at the proposition in that way. For when the architect is given a free hand his troubles begin. The modern steel building is more difficult to harmonize with the traditional rules of architecture than any other kind of building that was ever invented.

One of these traditional rules is, for instance, that the building shall look to be what it really is, that it shall not be a sham, that it shall be sincere. Now a modern steel building has a steel frame. Yet, on the outside, it looks as if it were made of stone and brick and terra cotta. This is clearly inconsistent. And it is an inconsistency that runs all the way through the building.

In many a steel building, for example, you will find beams that are carried across the ceiling in certain big rooms and that look as



SECTIONAL ELEVATION.

if they were supporting the ceiling. Yet, if you are familiar with construction, you know that they are not supporting the ceiling at all.

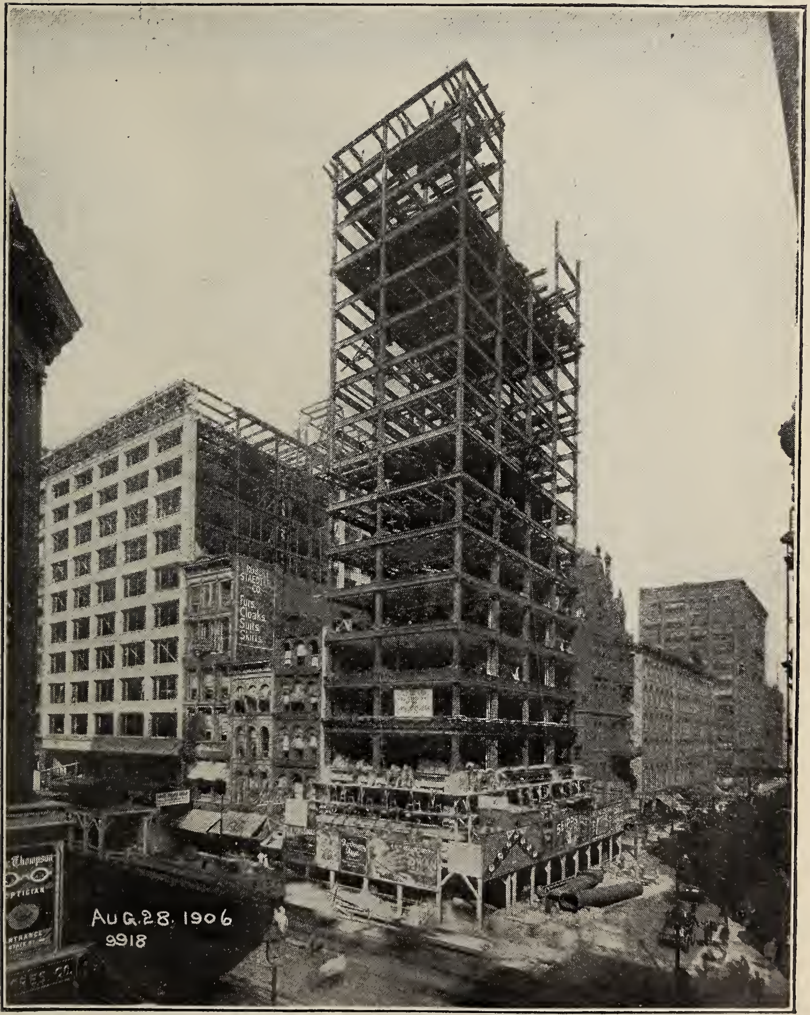
These beams are simply made out of plaster and other similar materials. They support nothing. They are themselves supported by the floor arches and the beams and girders. They are not architectural construction. They are simply architectural decoration.

These grand columns that we see so often on the exteriors of buildings might theoretically be supposed to consist of big, single pieces of stone or marble, worked into the proper shape. As a matter of fact, they are in all probability nothing of the kind.

If they resemble a great many of the columns that have been erected in modern times they are built out of a series of separate pieces about five feet in height, these pieces being placed one on top of the other. It frequently happens that the eye is even more grossly deceived. Each piece of the column (technically called a drum) may consist of several smaller pieces tied together with pieces of metal called dowels. The column may be hollow in such cases or may have concrete work and masonry inside it. It may also be anchored by other pieces of metal to a steel column. The architectural column then consists of metal, of concrete, of masonry, of hollow spaces, and of pieces of stone joined together to form drums which then, arranged in a vertical series, produce a column-like effect.

Such a column is extremely painful to some people. But this is merely incidental. The fundamental difficulty is to make a steel building look sincere, that is, to make it look like a steel building.

Now the central fact in a steel building is the steel column. Yet how can the fact of the existence of steel columns be even indicated to the occupant of the building? In the first place, it has to be concealed with terra cotta in order to render it fireproof. In the second place, it has to be still further concealed in order to make it attractive to the average eye. The steel column, by itself, is a com-



CHICAGO SKY-SCRAPER, SHOWING STEEL ERECTED AWAY IN ADVANCE OF MASONRY.

paratively narrow and superlatively angular and ugly thing. People demand that it be padded out and made to look symmetrical before it is allowed to appear in the walls of the finished rooms. If the steel column were exhibited to the tenant in its original shape it would look sincere, but its sincerity, like that of many human beings, would not bring it many friends.

The difficulty we have with the column is the difficulty that exists for the whole building. The frame of the building must be of steel. Yet it is very puzzling to discover any way of finishing the rest of the building with any reference to that fact. As things stand to-day, the modern office building continues to look as if it depended on masonry while in reality it depends on metal.

THE WORKS OF THE VANCOUVER POWER COMPANY (LTD.).

E. B. Hermon, '86.

The birth of Vancouver, British Columbia, may be said to date from the building of the Canadian Pacific Railway, and its extremely rapid growth to a city with a population of over 50,000 marks an era in the history of the marvellous development of the Pacific Coast. Situated on the eastern shore of the island-protected waterways characteristic of the North Pacific, surrounded by mountain ranges towering four to seven thousand feet above sea level, possessing a magnificent harbour, and being the terminus of trans-continental railways, Vancouver was destined to become a place of magnitude and importance.

In keeping pace with the rapidly increasing demand for power, light and street car service, the electric interests in Vancouver at length found a limitation to the numerous additions to their original steam plant. In the course of a few years one unit after another had been installed, until many different types and sizes of machinery were represented in the power station.

While a large quantity of some of the finest steam coal on the coast is mined within sixty miles of Vancouver, and notwithstanding the fact that the city has every natural advantage for obtaining a good supply of coal at reasonable rates, monopoly decrees otherwise, and in consequence at an early date investigations of the possible sources of hydraulic development in the neighboring mountains were commenced. Measurements of three available streams, Seymour Creek, Coquitlam and Stave Rivers, were taken at intervals, but, owing to the very large investment required for the development of hydraulic power on any one of them, and the comparatively small market afforded by the city of Vancouver, ten years elapsed before threatened competition awakened the electric interests to the necessity of taking immediate action as a measure of self-protection. Not until this time were the wonderful possibilities of development exemplified in the present plant of the Vancouver Power Co., Ltd., fully realized.

Early in 1902, a very careful examination and report was made upon the relative advantages of Coquitlam and Stave Rivers as sources of hydraulic power, and upon the general method and cost of the proposed development. Upon the basis of this report, which called for an expenditure of approximately $1,000,000, the undertaking was financed by the British Columbia Electric Railway Co., representing the electrical interests in Vancouver, and on the 15th of August, 1902, construction was commenced.

Reference to the accompanying maps makes clear the general plan of the development, the chief features of which are the dam at the outlet of Coquitlam Lake for the diversion and the creation of storage, a tunnel connecting Coquitlam with Trout Lake and serving as a water conduit, a dam across the outlet of Trout Lake and pipe lines from this dam to the power station, situated on a navigable arm of the sea, just above high tide.

Coquitlam, the main source of supply, is a glacial lake, having an area of 2,300 acres at an elevation of 432 feet above the sea level. The drainage area is approximately 100 square miles, and the annual precipitation over this area is about 150 inches. Measurements of the flow taken at the outlet of the lake over a period of thirteen years, show that the lowest stage of water ever recorded occurred in September, 1904, when the flow was 300 cubic feet per second for a period of nearly fifteen days, gradually increasing until on November 30th the flow was 5,000 cubic feet per second.

Trout Lake, used as a balancing reservoir at the head of the pipes lines, is separated from Coquitlam by a mountain range rising 4,000 feet above its waters, and the horizontal distance between the two nearest points of the two lakes is 12,775 feet, or nearly two and a half miles. The lake is situated close to the north arm of Burrard Inlet, and is distant about sixteen miles from the city of Vancouver. Its area is approximately 500 acres, and its elevation above the sea level 400 feet, making the difference in elevation between Trout and Coquitlam lakes exactly 32 feet.

Owing to the steep, rocky slopes and perpendicular cliffs of the mountains separating the lakes, it was found impracticable to carry the line of levels over the range, and accordingly four series of levels were run from portal to portal of the proposed tunnel, a distance of twenty-five miles around the end of the range, with the remarkably small maximum variation of 0.23 foot, determining the difference in elevation of the two lakes.

TROUT LAKE DAM.

For the alignment of the tunnel a Buff transit was used, having a large, high-power telescope. The instrument proved most satisfactory, and no trouble was experienced in setting points 9,300 feet distant. For convenience in communicating between the different stations, three signal men from the local militia were employed using flags and the usual code, which method was found to be a great aid.

Four stations were established, of which two were on the mountain, 3,200 feet apart, one on the further shore of Coquitlam Lake, and one on the further shore of Trout Lake. From the station on Coquitlam Lake to the summit of the mountain the distance is 7,901 feet, from the summit to the lower station on the mountain 3,203 feet, and thence to the Trout Lake station 6,170 feet. Owing to the contour of the mountain sides, neither tunnel portal could be seen from the stations on the range, and it was therefore necessary to produce the alignment back across the lakes.

When both ends met the closing error in alignment was found to be only seven-eighths of an inch, and the error in the levels only 1¾ inches.

In August, 1902, temporary camps were established at each portal of the tunnel, and the work of clearing the extremely heavy timber commenced. During September open cutting at the portals was carried on by driving temporary headings through the gravel and clay deposits and then breaking down from above. At the Trout Lake heading solid rock was found at a distance of 120 feet from the shore, and at Coquitlam only 80 feet of open cut was necessary.

Hand drilling was employed at each heading until January of 1903, when the installation of compressor and haulage plants at both portions was finally completed.

Owing to the uncertain nature of the work, it was decided after an examination of the tenders on tunnel work to let the contract on a percentage basis, based on a sliding scale in which the contractor's profits are increased in proportion to the decrease in cost per foot from the tendered price and an independent bonus provided for speed.

From an engineer's standpoint this form of contract is advantageous, since it places him in complete control of the work that ordinarily falls to the contractor.

The tunnel construction plants were furnished by the Vancouver Power Company, and the following grades were adopted for drainage and haulage: From the Trout Lake portal the tunnel has a rising grade of 0.14 per cent. for 6,300 feet, and thence a decline of 0.02 per cent. for 5,600 feet to the drainage sump, where the pumping plant was located. From thence a rising grade of 6 per cent. for 875 feet to the Coquitlam portal.

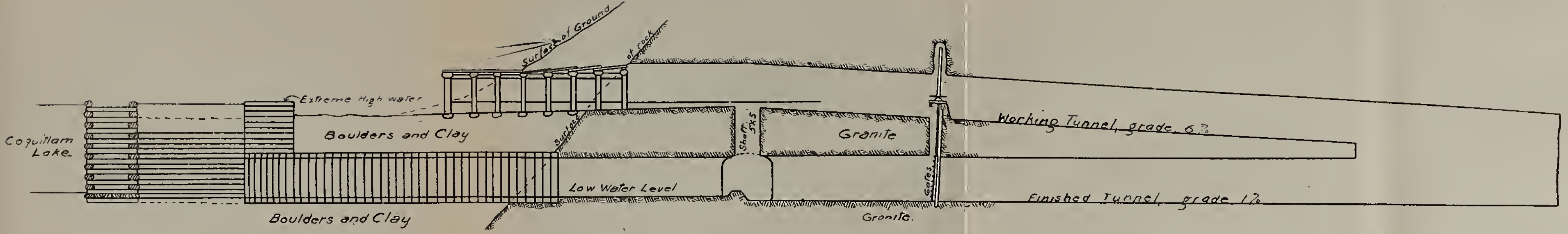
A short line of thirty-six inch gauge railway was run from salt water to the Trout Lake tunnel portal, the first section of which is 1,800 feet in length, and has a rise of 400 feet. This portion is operated by a Lidgerwood hoist having a pull of 2,000 lbs., while the balance of the road is level and is operated by an electric locomotive.

The tunnel plant at the Trout Lake portal consists of an eighty horse-power brickyard type boiler, an Armington and Simms high-speed engine, driving a sixty kilowatt direct current 550 volt generator, supplying current for lights, ventilating motors and electric haulage, and a Leyner two-stage air compressor, having a capacity of 400 cubic feet of free air per minute. At the Coquitlam portal a duplicate plant was installed with slightly greater boiler capacity in anticipation of pumping as the work progressed. For the transportation and installation of the latter plant it was necessary to build two miles of new road through a dense forest and swamp and to rebuild seven miles of old road and bridges. Of the nine miles of road nearly four miles were corduroyed owing to the boggy nature of the ground.

The normal sectional area of the tunnel is seventy-three square feet, the section being 9 x 9 feet, with rounded corners. The method of procedure in attacking the face or heading was as follows: A tunnel bar five inches in diameter and nine feet in length was first set in position across the tunnel and about three feet below the roof, the miners standing on the muck of the previous blast. From this position of the bar, three back or upper holes, four breast holes and four cut holes were drilled. The uppers were dry holes and formed the roof. The breast holes were wet holes, i.e., having a slight dip below the horizontal, and the cut holes had a slope of about 30 degrees below the horizontal. While these holes were being drilled, the muck from the previous blast was removed and the bar then lowered, and four "lifters" drilled under the bar to take out the floor to grade. During the time the miners were drilling the "lifters," the muckers laid mucking plates of quarter-inch iron about four feet square on the floor of the tunnel for a distance of thirty feet back from the face, removed dull steel and cleaned up for the blast. The iron plates afforded a suitable floor for shovelling the broken rock after a blast and greatly facilitated the speed of mucking, which work was done by nine men working three eight-hour shifts, two men shovelling at a time and one resting. About sixty tons of rock were removed each twenty-four hours.

Besides the compressor, a receiver having a capacity of 100 cubic feet of air was provided at each portal, located just outside the tunnel. Four-inch standard pipe was used underground for a distance of half a mile from the receivers and three-inch pipe for the remaining distance, with about 200 feet of two-inch pipe as temporary connection between the three-inch pipe and drills. To overcome the trouble due to wet air, short drops were placed at one-half mile intervals in the air line, and drip cocks on the pockets were left "cracked" to expel the condensed moisture when trapped. Flanged unions were provided at 500-foot intervals to facilitate repairs, and all joints were made up with oil and graphite, the pipe threads being run over with a die before taking the pipe into the tunnel. With sufficient care in making the joints no leakage was apparent.

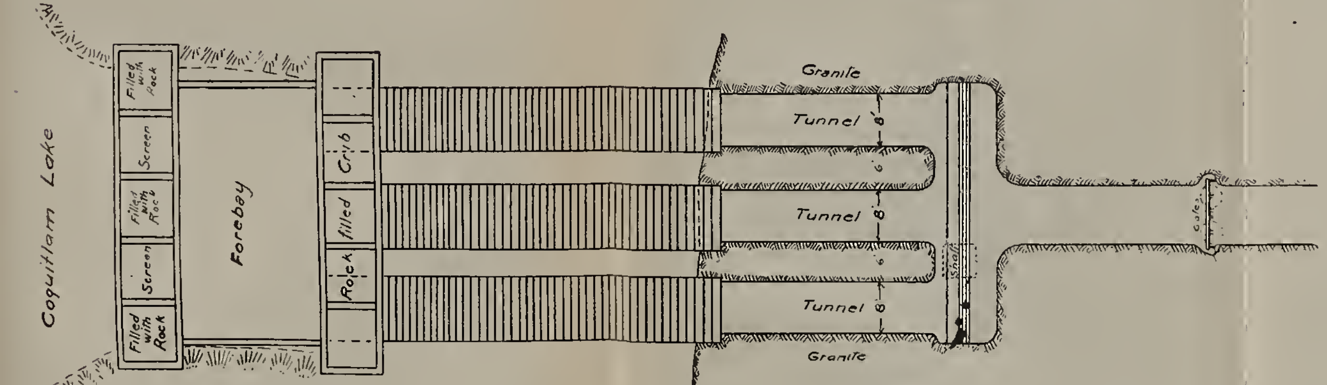
The work was started with four three and one-quarter inch Little Giant rock drills at each heading, two being constantly in service, and two in the repair shop or ready for use. These were used for nine months with an air pressure of 100 lbs. per square inch. As work progressed the rock became harder and larger drills, three and five-eighths inches in diameter, and seven-inch stroke, of the same type, and using 100 lbs. pressure, were installed. A number of different types of drills were tried on the work, some of which gave excellent results, but the Rand Slugger drill with piston



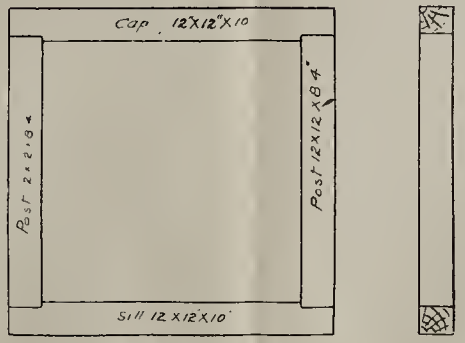
Section of Intake and Protection Works.

Coquitlam Lake Portal.

Coquitlam Tunnel.



Plan



Detail of Timber Sets

valve proved preferable to the miners and these were finally adopted. Speed being an important factor in the work, the drills were worked to the utmost limit, and the cost of repairs has been comparatively high per foot advance. The policy of keeping machines in the best possible condition had been constantly followed, and in December, 1904, new shells, cylinders and pistons were provided for each machine. Experience on the work has shown that the useful life of a machine drill under the conditions obtaining is at most twelve months, and resembles the old maid's stockings, which she wore for five years—repairs, five new feet and two new legs.

The shanks of the drills used were of one and three-eighths-inch Octagon Crescent or Canton steel, fitted with one and one-eighth inch bushings for the chucks. The bits were welded to the shanks and made of cruciform steel, varying from one and one-quarter inch to two and one-quarter inches in diameter, and swedged out to from one and one-half inches to two and one-half inch bits in one-quarter inch variations. Drill sharpening was done by a blacksmith and helper at each heading with the use of special tools. Tempering was done by cold running water and also by dipping in a mixture of prussiate of potash and water, followed by a plunge in cold water. Good results were obtained by each process, and under ordinary conditions each steel will drill from eighteen to twenty-four inches with one sharpening.

On an average 120 drills were sharpened per day with the use of 100 lbs. of blacksmith coal.

Owing to the fact that cars of sufficient capacity capable of being dumped by one man could not be obtained, special cars were designed and built. These have a height of only thirty inches above the rail and a capacity of two cubic yards. The bodies are of steel and swing on a centre king-bolt, dumping out of one end and on either side of the track. The cars weigh 1,500 lbs. and are equipped with twelve-inch, standard pattern chilled wheels, pressed on to two and one-half inch axles. The cost of the cars was $130 each.

A General Electric locomotive with double equipment, consisting of two ten-horse power, 500 volt motors, and series-parallel control, having a draw-bar pull of 1,200 pounds, was provided for haulage at each heading. Each locomotive readily handled two loaded cars on a six per cent. grade, developing thirty-two horse power for about a minute and a half. They were worked at a speed of from four to six miles per hour and proved eminently satisfactory, costing very little for repairs. Two motormen working twelve-hour shifts handled the cars from the face of the tunnel, dumped them and loaded all sharp steel taken into the tunnel.

As the tunnel penetrated the mountain, the question of ventilation had to be met, and a solution was reached by the installation of a twelve-inch galvanized iron pipe of number twenty-four gauge, at a cost of 7½ cents per pound. Forty-inch Sturtevant fans, driven by five-horse power motors, were placed at 2,000-foot intervals, working in series, each fan forcing the air to the next one in the line. The speed of the fans was between 1,300 and 1,400 revolutions per minute, and served to clear the tunnel of gas and smoke in forty-five minutes after a blast. At the same time compressed air was blown through a one-quarter inch opening into the face and aided in forcing the gas back to the end of the twelve-inch ventilating pipe, which was kept about 100 feet away from the face, out of reach of flying rock and debris. As the ventilating pipe was subject to extremely heavy concussions, a very strong and rigid plan of holding it in place had to be adopted.

Several methods of lighting the tunnel were tried, but all were abandoned in favor of candles, which, though expensive, were best suited to the miner's requirements. The plants and camp buildings were all electrically lighted.

The fuel item for camps and plants proved expensive, owing to the difficulty of landing the wood at point of use. At the Coquitlam portal, logs were felled into the lake from the shores and towed to the vicinity of the camps, where they were cut up into four-foot lengths while in the water and then hauled out on an incline by means of the electric locomotives and steel blocks with wire cable. Sawing was done with a drag saw driven by a five-horse-power motor. At the Trout Lake heading the logs were hauled out with a donkey engine and hand sawn.

The working tunnel floor was begun at the Coquitlam portal at an elevation of five feet above high water level in the lake, for safety during construction. During the progress of the tunnel proper, a shaft was sunk in the floor of the working tunnel at a point thirty feet from the portal, to a depth of eighteen feet, the floor level of the finished tunnel. From the bottom of the shaft, a cross cut, or heading, was run at right angles to the tunnel for a distance of twenty feet on each side of the centre line. The cross section of the heading is ten feet by ten feet, and from it three eight-foot by eight-foot openings, parallel to the tunnel, were driven into the lake, forming a submerged intake. From the centre of the cross-heading and directly under the upper working tunnel, the finished tunnel was driven on a one per cent. grade to meet the former, which has a grade of six per cent. to the portal. While this necessitated the driving of some 300 feet of extra tunnel, it insured freedom from lake water and interruption to the work. During construction, and until the tunnel headings met, about ten feet of rock was left in place in each of the three intake tunnels to guard against flooding.

For control of the flow of water through the tunnel two gates are provided in the main tunnel at a distance of sixty feet from the Coquitlam portal. The upper, or working tunnel, has been converted into a gallery from which the gates are operated by means of screw stems, ball bearing nuts and hand wheels, resting on a framework fastened rigidly to the rock by anchor bolts, while all the spaces between frame and rock are filled with concrete for water tightness. The gates are each four and one-half feet by nine feet, built up of structural steel and carrying on each side brass rollers, running on "I" beams, which form the framework. The gates carry flanges on each side, which seat only when the gates are closed.

The formation of the mountain mass pierced by the tunnel consists essentially of syenite or quartz syenite, a granitoid rock, consisting of quartz, feldspar and horn blende, with occasional dykes of diorite. The rock increased in hardness from the surface and the diorite was found invariably hard and tough. The structure was very uniform and hard, no timbering being required on the entire length of the tunnel.

Temperature readings were taken at each 1,000 feet advance and showed a rise of only two degrees for each reading. The maximum temperature of sixty degrees F. was reached at a distance of 3,500 feet below the surface and 6,000 feet from the portal.

The dam at the outlet of Coquitlam Lake is a rock-filled timber crib structure.

The cribwork is made of twelve-inch by twelve-inch sawn timbers, placed six to seven feet apart, centre to centre, and drift bolted together with three-quarter inch drift bolts. The apron consists of twelve-inch by twelve-inch by thirty-eight-foot timbers drift bolted to twelve-inch by twelve-inch sills, and also drift bolted to one another laterally. Below the main apron there are two smaller ones, one on each side of the river, which protect the abutments and prevent any undermining from the action of the water.

The river bottom on which the foundation rests consists of a pavement of large boulders, underlying which is glacial hard pan.

Along the upstream toe of the dam these boulders were removed and a trench dug into the hard pan; a double row of sheet piles was then driven along this trench and spiked to the twelve-by-twelve timbers, the trench being refilled with the best available material, well rammed. The top sheeting consists of a double thickness of planking, the bottom planks being four inches, and the top ones two inches in thickness. The length of the dam is 113 feet and its height is 14 feet. The top width is 12 feet and the width at the base 50 feet, not including the apron.

The reasons for the unusually extensive apron to this structure will be better understood when it is known that at flood water large fir and cedar drift logs six to eight feet in diameter pass over the dam.

The dam was built by day labor, except the sawing of the timber. This was all cut near the dam site at a cost of $15 per thousand board measure and consists chiefly of hemlock.

A portable sawmill was erected at a point about 700 feet upstream from the dam, and the sawn timber was dumped into the stream and floated down to the work, where it was picked out of the water by derricks (one on each side of the river), put into place by only one handling and immediately drift bolted.

The derricks were operated by a donkey engine and were used also in placing the rock filling in the cribs.

The total amount of timber used in the structure was 600,000 feet board measure, and the cost, including the intake crib and head gates for the City of New Westminster water pipe, was $25,000.

As there was not sufficient rock to be had in the immediate vicinity of the dam to complete the filling, a quantity was brought from a point upstream, where a quarry was opened and a short tramway built to haul the rock to the dam.

The work was only partly finished the first season, as its completion would have flooded the tunnel. The abutments, foundation timbers and aprons were put in and covered over with temporary planking. This planking was removed and the rest of the work completed after the tunnel was finished.

The dam across the outlet of Trout Lake was built by day labor, and is located at a point where the creek passes through a deep ravine about half a mile from the lower end of the lake.

Before deciding upon the location, a large amount of preliminary work had to be done in order to ascertain the nature and exact position of the underlying bedrock, which was covered over with a thick variable stratum of hardpan. This hardpan had to be drilled and blasted, and owing to the numerous large boulders it contained, was difficult material to handle.

Ten shafts were sunk through the hardpan, varying from twenty feet to fifty-four feet in depth, and connected by drifts running along the bedrock.

When the final location was decided upon, the site, which was covered with a dense growth of large fir and cedar timber, was cleared and a temporary dam built at a point about 100 feet upstream. This dam was a long crib structure with a rock filling about twenty feet in height and cost $1.00 per cubic yard of contents. It was necessary to give it sufficient stability to withstand flood water, which at one time passed over its entire crest.

A flume was built from this dam and extended down along the creek bed for about 600 feet, past the site selected for the permanent dam.

In order to make the excavation for the permanent dam, a donkey engine and large boom derrick were installed on each side of the creek, and as the material was excavated it was dumped into the flume by means of the skips and sluiced away. All large boulders met with were picked up and placed to one side and afterwards used in the concrete filling.

In this way 20,000 cubic yards of material was removed, most of which passed through the flume, being handled only once.

This ground was of such an exceptionally hard nature that no impression could be made upon it with picks, so that it had to be drilled and blasted. Some of the boulders met with were very large, containing as much as five cubic yards, and at first were mistaken for bedrock.

After the excavation was completed the surface of the rock was washed clean and carefully examined for the entire length of the dam and all loose pieces and partially decomposed rock removed. It was found to be syenite of a good sound nature and most favorable for the foundation of a dam.

The bedrock, after being thus prepared, was drilled with small holes six inches deep, and three feet apart, which were loaded and fired, producing a rough surface, such that a good bond would be made with the concrete.

In building the base of the dam no forms were used, but the entire width of the excavation was filled in with concrete, and brought up to a level surface, after which the form timbers were put in place.

The concrete consisted of one part Portland cement, two and one-half parts sand, and five and one-half parts crushed granite.

Along the upstream face of the dam a little different mixture was used for a thickness of about eighteen inches. This contained more cement, the object being to secure water-tightness.

The concrete was mixed with a gravity mixer, which emptied into a skip. It was then removed with a derrick and placed in the work. The mixer was hung on rollers and did duty for skips which it filled alternately.

The concrete was placed in the dam in layers about ten inches in thickness, and so built up that frequent jogs or offsets were left to make a thorough bond with the following course.

Before commencing a new course, the top of the foregoing one was roughened with picks and then washed off clean with a hose. The concrete was then put into place and trimmed with shovels and well tamped.

It was found that the best results were obtained when the concrete was made rather wet; this was especially the case when boulders were placed into the work. The concrete work was carried on day and night, and was completed within five months of its commencement. Were it not for the fact that it was impossible to get sand delivered to the work in sufficient quantities to keep the entire force of men employed, this work could have been completed in a much shorter time.

In one ten-hour day shift 105 cubic yards were placed, and in one nine-hour night shift 87 cubic yards, making a total of 192 cubic yards of concrete work in one day.

The sand used came from the sea bottom near the mouth of the Fraser River, where it was pumped on to scows and then towed to the landing, where it was loaded into cars, hoisted up the hill by means of a steam hoist and delivered to the dam, where its cost amounted to about $1.00 per cubic yard. This sand, although not coarse, was very clean and sharp and produced first class concrete.

The rock used in the work was quarried out of the hill side at a point about 300 feet from the work. It was loaded into cars and landed at the crusher by means of a small gravity tramway. The top of the dam was built up to the level of Trout Lake. It has a length of 361 feet and a maximum height of 54 feet. It has a width of 35 feet at its base, and a top width of 7 feet, and contains 10,000 cubic yards of concrete.

There are ten fifty-four-inch steel pipes and two twenty-four-inch pipes penetrating the dam at a point twenty-two feet below its top. These pipes are all fitted with special roller gate valves at the face of the dam, with separate screens for each pipe.

Four different brands of Portland cement were used in the work, viz., White Bros., Hercules, Condor, and Alsen.

These cements were all tested as the work progressed, each shipment being sampled.

There were 12,400 barrels of cement used in the dam at a cost of about $3.50 per barrel delivered at the work.

The excavation cost $1.00 per cubic yard and the concrete work $8.50 per cubic yard.

The cost of the work was made considerably greater than it otherwise would have been on account of the high rate of wages for common labor which prevailed, and the poor class of labor available. The night work also added to its cost. The sand had to be pumped from the sea bottom, and in rough weather it was impossible to get it delivered fast enough to keep the force employed.

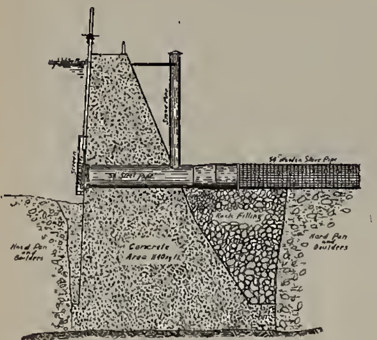
The intake gate valves are placed in guides bolted to the face of the dam and are fitted with brass rollers, on which the thrust due to the water pressure comes. A circular ridge on the back of the gate is machined to make the seat and a corresponding seat is

— VANCOUVER POWER CO. LTD. —
CONCRETE DAM
AT
OUTLET OF TROUT LAKE

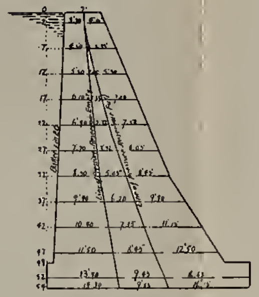
Total Excavation in hard pan and boulders	20,000 cub yds.
Total Contents of Dam	10,000 " "
Total Quantity of Portland Cement Used	12,400 barrels

Brands, White Bros Alsen, Condor, Hercules,
Concrete composed of
1 Part Cement, 2½ Parts Fraser River Sand, 5½ parts Crushed Granite
Specific Gravity of Concrete · 2·35
Factor of Safety 2·53

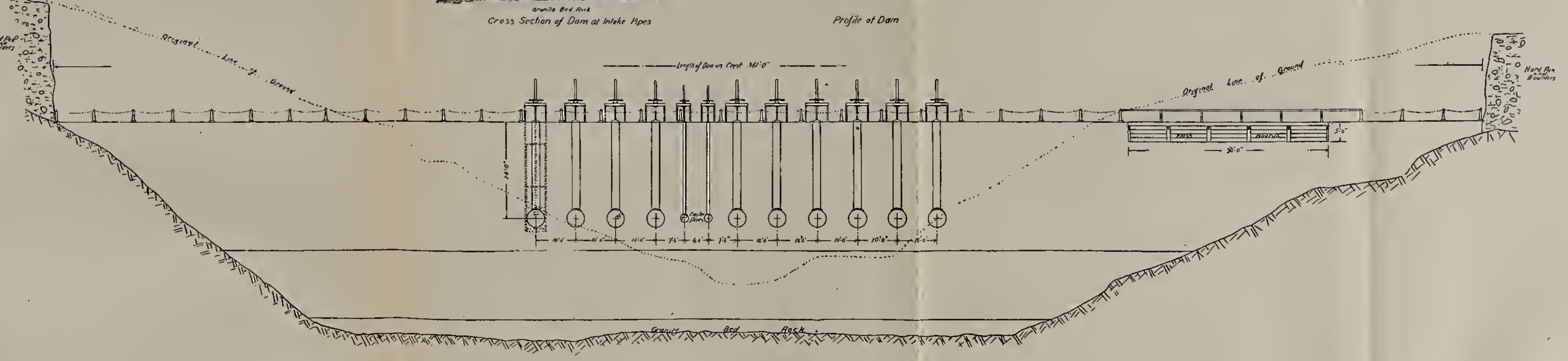
W. Meredith
Consulting Engineer
E. B. Hermon
H. M. Burwell
Engineers



Cross Section of Dam at Intake Pipes



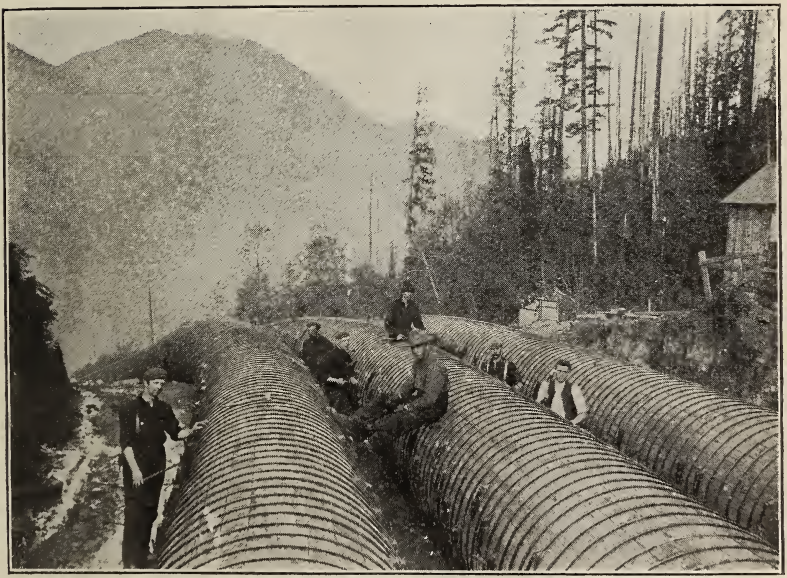
Profile of Dam



Elevation of Dam showing Rear Face

No. 185

made on the gate frame, to which the pipes are riveted. These seats are not quite parallel to the plane of the rollers, so that when the gate is lowered to a certain point it takes its seat and the pressure on the rollers is relieved, but immediately the gate is raised a fraction of an inch the pressure comes on the rollers again. The gear for operating the gate is a simple screw stem and hand wheel, with roller bearing which takes the pull. The gates are quite tight and can be operated with ease by one man at all stages of the water.



FIFTY-FOUR-INCH WOODEN STAVE PIPES. SPIRAL CURVES.

There are fifty acres of land lying between the dam and the lower end of Trout Lake, which have been flooded, and a central canal about fifty feet wide and twenty feet deep was excavated, connecting the new lake with Trout Lake. This gives a reserve or storage of water of about sixteen feet in depth over an area of 500 acres, which can be utilized when required, and forms a balancing reservoir.

This enables the attainment of very high peak loads and reduces the waste of water to a minimum, for immediately the water is shut off at the power house it commences to store in this reservoir instead of running to waste.

The pipe lines extend from the dam to the power house at sea level, for a total length of 1,800 feet, and are built to curves and tangents both vertically and horizontally, no angles being allowed.

The pipe line was graded and the pipes laid in the trench by day labor ready for riveting. The pipes were made and riveted together on the ground by the Vancouver Engineering Works, Ltd., of Vancouver, B.C.

The first trench excavated was made to accommodate five pipes; it passed over a vertical rock bluff seventy feet in height which had to be cut down, and at the lower end in order to extend the pipes into the power house it was necessary to put two short tunnels through the rock, 110 and 135 feet in length, respectively. These tunnels were built in curves with 200 feet radii.

On one portion of the pipe line, where a creek is crossed at the foot of the bluff, it was necessary to lay the pipes on temporary trestles, which were constructed to suit the vertical curves taking place at these points. The trestles afterwards were used as false work, when they were finally replaced by concrete piers.

A tramway was built in the pipe trench for its whole length and operated by a steam hoist. In this way all the pipes were put in place, the track being shifted over laterally as each line of pipe was placed.

The average depth of the trench excavated was six feet, and the bottom was brought to an even surface. This enabled a track being laid along it, and greatly facilitated the handling of the pipes, and the building of the lines.

The material excavated was afterwards used to cover the pipes, all the rock being hand placed under the pipes, and the whole work covered up with the finer material and sown over with clover seed.

Where curves occur at the lower end of the pipe line, the pipes are kept in place by concrete piers set from twelve to sixteen feet apart.

The upper portion of each pipe line is of wooden stave construction, fifty-four inches in diameter, and extends from the dam for a distance of 800 feet to a point where it is under pressure due to seventy-five feet head. From this point to the power station the pipe lines are of riveted steel, varying in thickness from nine-thirty-seconds inch to seventeen-thirty-seconds inch and ranging in diameter from forty-eight inches to forty-two inches at the lower end.

At the present time three main pipe lines and one exciter pipe line are installed, and a fourth under construction, the total length of each of the steel lines being 1,000 feet. Each line is fitted with air valves at three different points, a relief valve at the lower end and a stand pipe just below the dam.

The exciter pipe line is constructed of steel throughout its entire length, and is twenty-four inches at the upper end and eighteen inches at the lower end. The thickness of plate varies from one-eighth to one-quarter inch.

The wooden stave pipes were built by the Excelsior Wooden Pipe Co., of San Francisco, and cost approximately $4.00 per lineal foot, the lumber being delivered at a cost of $37.50 per thousand feet board measure.

The cost of the steel lines was approximately $14.50 per lineal foot for the large pipes exclusive of excavation for the trench, which is 1,800 feet in length and about thirty-eight feet in width. This work includes about 400 feet of trestle and 250 feet of tunnel, also about 3,500 cubic yards of rock work in cutting down a bluff about seventy feet in height. The balance of the excavation was made through large boulders, gravel and hard pan, all of which was overtopped with a dense growth of immense cedar and fir trees.

The cost of the pipe line grading, including the hand placing of broken rock around the pipes, back filling, concrete piers and anchorage, amounted to about $25,400.

In designing the Vancouver Power Company's installation, the present demand for electric power, as well as the natural annual increase as shown by the records of the station, was considered. Accordingly, it was decided to instal the initial equipment for 9,000 horse power in three units. Convenience of handling and independent unit operation favored separate pipes lines. Each unit consists of one revolving field engine type 200 revolutions per minute, three phase, 2,300-volt Westinghouse generator, and two Pelton water wheels, one on either end of the shaft, taking water from a single pipe through a Y-connection and two deflecting needle nozzles, one to each wheel; the shaft bearings and bed-plate being furnished by the water wheel makers. The needles are adjustable by hand to suit the maximum fluctuation of load and the nozzles deflected by type Q Lombard governors.

The revolving fields were especially designed and constructed to withstand a runaway speed which might accidentally reach 175 per cent. or more. The hollow forged steel shaft carries the rotor centrally between the bearings, making a perfectly symmetrical arrangement and loading the two bearings equally.

Spatter water from the wheels is caught in a housing pocket and passed through the hollow shaft and also through the oil cellar of the bearings. The rotating element, including shaft wheels and field, weighs 80,000 pounds. The water circulation system has proved of great value in maintaining cool bearings.

Exciting current is provided by means of either one of two direct connected water wheel driven generators, coupled to an induction motor, taking current from the main bus bars. The motor not only insures exciting current in the event of wheel troubles, but serves as a governor absorbing as a generator the power of the wheel in excess of that required by the exciter.

The equipment is housed in a plain massive granite building, 40 feet in width and 160 feet in length, located just above high tide. As the granite bluffs extend almost vertically from the water edge, it was necessary to excavate a sort of shelf, not only for the present building, but for such future extensions as may be necessary to house the apparatus for an ultimate capacity of 30,000 to 40,000 horse power. Much of the excavated rock was landed directly in the water by the force of the blasts, the water immediately in front of the works being over 600 feet in depth.

Foundations are provided for the addition of a fourth unit of similar size and design; beyond this only excavation for power house extension has been provided. It is probable that further additions will consist of 6,000 horse power units or larger.

GENERATING STATION.

The switchboard is located upon a raised platform at one end of the building, affording the operator a complete view of the main floor. The board is of the usual construction, equipped with Tirrill regulators, a full set of indicating and recording instruments and automatic oil switches. Two sets of bus bars are provided, one for the constant lighting load and one for the variable railway and power service. Two single throw switches are used in place of the usual double throw switch, one connected to each set of bus bars. This permits of transferring a generator from one bus to the other or feeding them in parallel without opening the circuit, thus providing great flexibility and insuring smooth service.

In a concrete building on a small flat just above and back of the power house is installed the step-up transformers, high potential switches and lightning arresters. There are three sets of three 550-kilowatt air blasts, delta connected, transformers raising the voltage to 23,000 for transmission. The low potential side of these transformers is controlled by switches located on the main switchboard in the power house. The high potential side may be connected to either or both of two sets of bus bars and the four transmission circuits may in the same way be connected to either or both sets of buses.

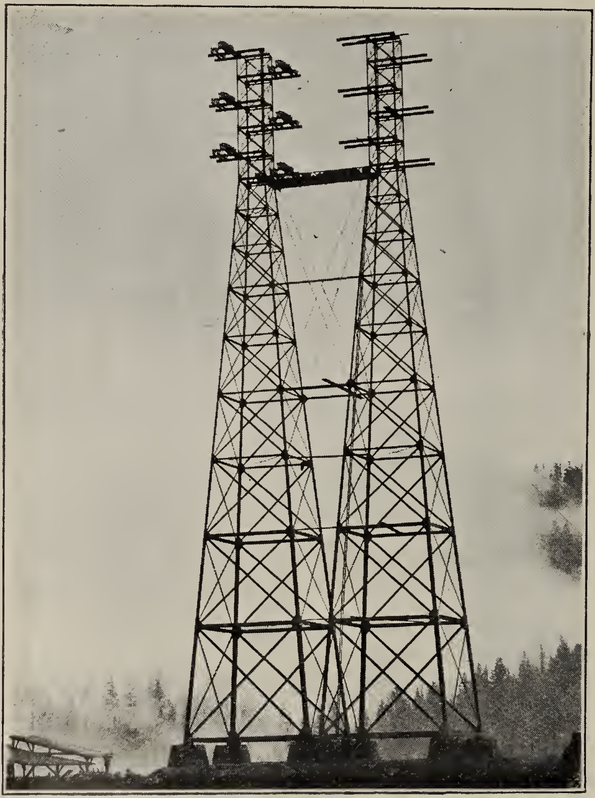
The many switches required for this multiplicity of connections are of special design, made at the company's works, and are perhaps of more than passing interest. They are of the bayonet air break type, and contain no oil. When a switch is closed the bayonet compresses a spring behind a piston which furnishes a slight blast of air at the precise moment the bayonet is withdrawn, thus blowing out the arc before any considerable metallic vapor is formed. The arc appears to be about one and one-fourth inches in length when breaking a 2,000-kilowatt 23,000-volt circuit. Westinghouse low equivalent lightning arresters are connected to each line, which is also provided with an ampere meter and a potential tell-tale.

Immediately outside of the transformer building there is inserted in each line a set of ram's horn emergency switches, which are operated from either in or outside points.

The double forty-five foot pole line carries four three-phase, No. 2 B. & S. gauge, medium drawn, copper circuits, two on each line. The wires are supported on nine-inch umbrella type Locke glass insulators, mounted on a special metal pin. At corners and points of extra strain the insulators are provided with a cast iron cap cemented on. The clearing of the right-of-way through the extremely large timber of the dense forest, characteristic of this locality, was an expensive piece of work, not usually met with in transmission line connection. For 100 feet in width the right-of-way was slashed, the brush and tops being burned and the immense logs rolled to either side. Outside of the 100 foot line all trees that might reach the line in falling, and there were many of them over 200 feet in height, were cut. The line from the power house to the Barnet crossing is built over a rough mountainous country, where wagon roads are impossible. Fortunately, there was found magnificent cedar growing on or near the right-of-way, from which all poles were cut. The cost of clearing alone amounted to $860 per mile.

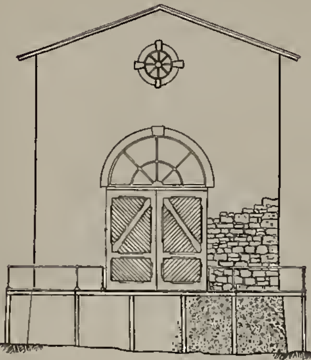
At Barnet the lines cross a navigable arm of the harbor. The distance between supports is 2,750 feet and the conductors are 150 feet above high tide at the lowest point. Twelve seven-strand nine-sixteenth-inch galvanized plow steel cables are used as conductors. High ground on the north shore and twin towers on the south shore form the supports of the doubly insulated saddles holding the cables. Each cable is anchored to eye bolts at either end. These are sulphured in solid rock on the north end and secured to a concrete monolith at the south end. Anchorage insulation for each cable is secured by means of a series of thirty-two of the nine-inch, glass, line insulators, which are provided with cemented iron caps and supported by metal pins held in a double angle iron frame. The insulators are mounted in pairs, the cable passing between them. The strain is transmitted to the insulators by means of a clamp on the cable behind an equalizing bar, which transmits the strain to an insulator on either side, equally distant from the cable, by means of two U bolts having a curve of slightly greater radius than the neck of the iron insulator cap. This design permits the use of ordinary line insulators for almost any span, and it is worthy of note that any insulator can be replaced quickly and without difficulty.

From Barnet the line is constructed along the highway almost due west nine miles to Vancouver. Three miles from Barnet one line runs south to the Barnaby sub-station, located on the tramway connecting the city of New Westminster with Vancouver, and thence along the railroad right-of-way to Vancouver, forming a loop. In this way the Vancouver and Burnaby sub-stations are served by two independent pole lines and four circuits.

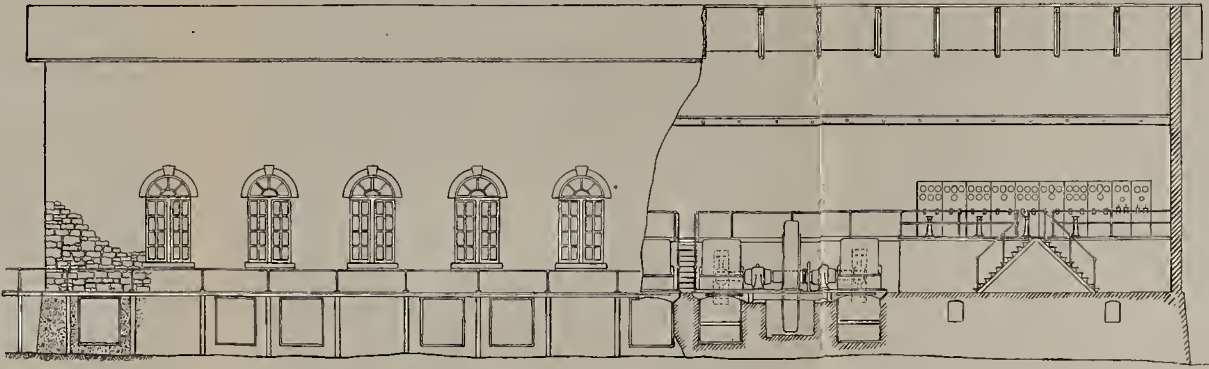


CABLE CROSSING — BARNET.

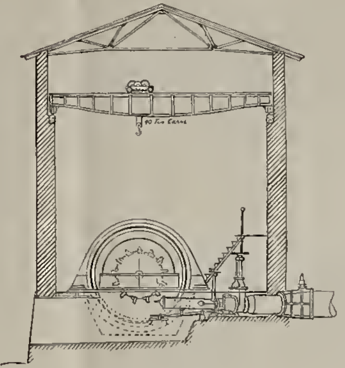
A four-mile branch line from Burnaby to a sub-station in New Westminster supplies the municipally owned distributing lines with current for both incandescent and street arcs. From Vancouver a branch line extends seventeen miles to the delta of the Fraser River, where another sub-station is located that supplies current for the Lulu Island electric road and lighting and power service



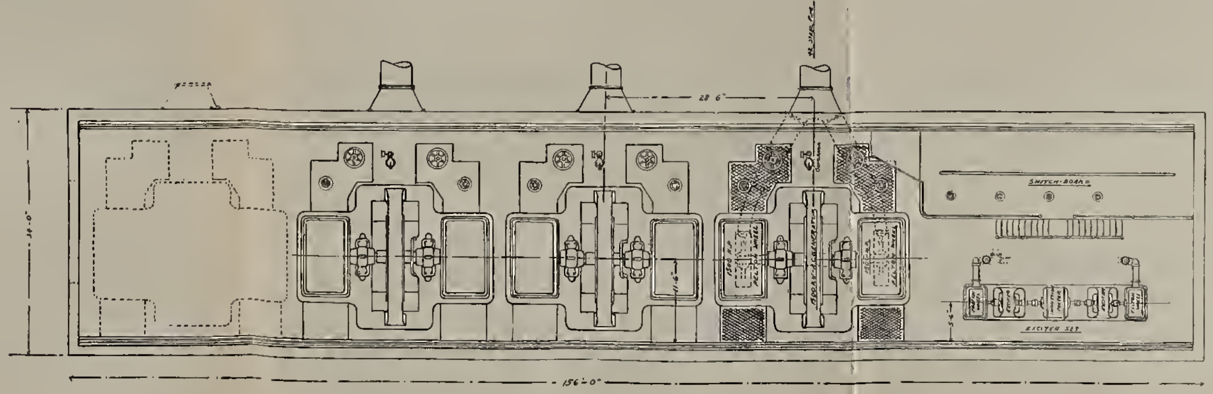
NORTH ELEVATION



SECTION & WEST ELEVATION



CROSS SECTION



PLAN

VANCOUVER POWER CO.
LIMITED
GENERATING STATION
AT
TROUT LAKE

Scale. 1/8 in. = 1 ft.

Vancouver, Dec 8th 1904

W Meredith
Consulting Engineer
E B Hermon
H M Burwell
Engineers

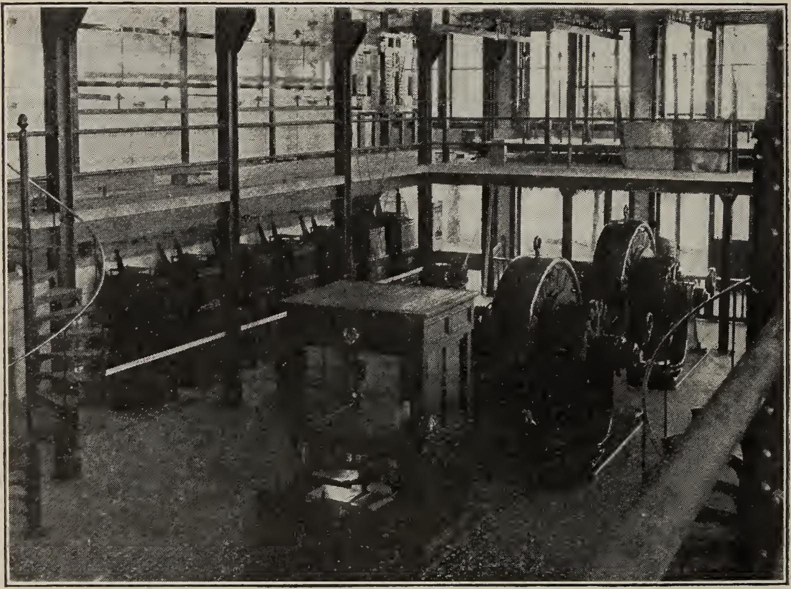
for Stevetown and Ladner, where the large salmon canneries are located. All sub-stations are of steel and masonry construction, designed for small fire hazard and low depreciation.

Transmission lines are all equipped with ram's horn, disconnecting switches, located just outside of the buildings and arranged for operation from the inside. Flexibility of connections is obtained by means of a set of single pole automatic air blast switches in each station, which permits of any combination of circuits being made.

VANCOUVER SUB-STATION.

From these switches two sets of high potential bus bars provided with low equivalent lightning arresters are carried to the step-down transformers, which are all of the air blast type.

The Vancouver sub-station is located on Westminster Avenue, one of the principal streets of the city, and is a fine, substantial building 60 x 120, with large plate glass windows facing the avenue. In addition to the basement and main floor, there is a steel and concrete floored gallery, eighteen feet wide on the front and both sides. The air blast switches occupy the front portion of the gallery and the lightning arresters and transformer switches are located on one side, the railway switchboard being on the other. Spiral stairs give ready access to the gallery on either side. The open space in the middle is reserved for rotary converters, and is provided with a hand-operated bridge crane travelling the length of the building.



INTERIOR—VANCOUVER SUB-STATION.

Railway current is provided by means of two 500-kilowatt and one 1,000-kilowatt rotary converters, with their complement of transformers, regulators and switchboard. Each rotary is provided with a direct connected induction starting motor and a direct current rheostatic starting equipment. The switchboard contains both alternating current and direct current rotary panels, a totalizing panel and feeder panels.

The lighting and power service in Vancouver is supplied by means of eight 500-kilowatt step-down transformers, "Scott connected," for two-phase, 2,300 volts. Current from these transformers is taken through a sixteen-panel switchboard, provided with a full complement of instruments and switches. The single-phase feeded circuits are each provided with a double-throw oil switch for connection to either phase for balancing purposes, a time limit controlled oil circuit breaker and independent regulators. Recording voltmeters are used on each feeder, taking current from a pair of pressure wires connected at the centre of distribution.

The first generator was started, and current delivered, December 19, 1903, water for the wheels being obtained from Trout Lake. The tunnel was completed and water delivered through it June 10, 1905. Commercial service has been given since the first unit was started, only one interruption having been noted to date, and that was caused by one of the large wood rats, which are found in this locality, having attempted to build a nest between two of the anchorage insulators at the Barnet crossing. The iron caps used on the insulators were partially fused, but prevented any injury to the cable. A few moments only were required in which to disconnect both ends of this line, when service was resumed over the three remaining circuits. From this experience it would seem that rats and similar animals will have to be counted a menace to electrical transmission lines, as well as birds.

Simplicity and durability were the chief factors considered during the design and construction of the plant. Its operation to date has demonstrated that in a large measure both have been attained to perhaps a greater extent than has been usual on the Pacific Coast.

The principal contractors connected with the undertaking were: Ironside, Rannie & Campbell, tunnel; Westinghouse Electric and Manufacturing Company, electrical equipment; Pelton Water Wheel Company, water wheels; Lombard Governor Company, governors; Vancouver Engineering Works, pipe lines and head gates; Jno. Martin & Co., insulators; Canadian Rand Drill Company, air drills; Geo. Leyner Company, air compressors; in addition to which a great

Table Shewing Daily Progress of the Coquitlam Tunnel

Coquitlam Lake Heading

	DAILY PROGRESS		DRILLING								BLASTING			MUCKING			GENERAL WORK								SUPPLIES		
Day Ending at Midnight	Advance in Lineal Feet	Excavation in Cubic Yards	Machine Drills in use	Machine Men, Number of	Hours Worked	Helpers, Number of	Hours Worked	Holes Drilled, Number of	Total Depth of Holes Drilled	Powder, Pounds used	Fuse, Feet used	Caps, Number used	Muckers, Number of	Hours worked	Cars of Rock run out	Motor Men, Number of	Engineers Number of	Firemen, Number of	Other labour under ground, No of	Blacksmiths, No. of	Blacksmiths' Helpers	Drills, No sharpened	Other labour above ground, No. of	Wood, Cords burned	Coal (Blacksmith)	Candles, No. of
Monday .. 13	6	19	2	12	120			26	143	84	230	23	9	72	31	2	2	1	2	1	1	117	10½	5½	119	103
Tuesday 14	10	32	2	14	120			26	143	122	440	44	9	72	25	2	2	1	2	1	1	122	10½	5½	119	103
Wednesday 15	10	32	2	14	120			34	187	171	450	45	9	72	34	2	2	1	2	1	1	127	10	5¾	119	103
Thursday 16	10	32	2	14	120			30	165	150	460	46	9	68	35	2	2	1	2	1	1	135	10	5¾	119	103
Friday 17	10	32	2	14	120			30	165	170	550	55	9	72	36	2	2	1	1½	1	1	107	10½	5¾	116	102
Saturday....18	10	32	2	14	120			28	154	218	590	59	9	72	31	2	2	1		1	1	114	10½	5¾	116	103
Sunday 19	10	32	2	14	120			28	154	200	560	56	9	72	33	2	2	1		1	1	133	11	5¾	117	103
	66	211	2	96	840			202	1111	1115	3280	328	63	500	225	14	14	7	9½	7	7	855	73	39¾	825	720

REMARKS: Ground medium drilling, but required a great deal of shooting

CAR REPAIRS nil.

DRILL REPAIRS, ETC. June 13th 1 chuck bolt + nut, 1 oil plug, 1 shaft bar screw, - 14th 1. Standard, - 17th 1 Rocker pin, 1 Slide valve, 1 leather piston packing ring - 1 packing 2 hours, - June 18th 1 Pawl + Spring, 2 pawl bolts, 2 packings 4 hours, 1 hour cutting side rods, 19th 1 pawl bolt, 1 chuck bolt, 1 Standard 2 hours labour.

For week ending June 19th 7 am., 19034

Wallace Fraser
FOREMAN.

many contracts were placed with local firms for the smaller machinery, supplies, etc. The steel towers and cables used at the Barnet crossing were made in England and brought out via China.

The whole system of this water power development was originated by Messrs. Hermon & Burwell, and the engineering was performed by Mr. Wynn Meredith, Consulting Engineer, and Mr. E. B. Hermon and Mr. H. M. Burwell, engineers in charge of the construction.

RAILWAY SURVEYS.

Andrew F. Macallum, B.A.Sc.

The responsibilities of a railway engineer to his clients or company are as great as those of a trustee intrusted with the investment of others' funds. Upon his opinion and estimates large sums will probably be expended, and for this reason he must be conservative in recommending any investment where the margin of profit is small. The collateral obligations of a company building a railway will very often be sold or subscribed to upon information contained in his report. He will probably have to listen to glowing reports of promoters and speculators if the proposed line be through a settled country. None of these, however, should enter his report until he has carefully investigated and satisfied himself as to their truth.

The railway engineer must remember that his road is to be built for the convenience of the public, as upon that fact will often lie the financial success of the enterprise. A railroad may be built which, according to engineering standards, may be perfect, where the cost per ton mile or car mile is extremely low, and yet be a financial failure, owing to a disregard of public convenience. It is always wise to locate a line as close to an existing centre of population as the engineer dare risk, having regard to the fixed charges which he thinks his road can stand. As a rule, with few exceptions it has been found that centres of population do not transfer themselves for the benefit of the railway, and it is almost certain that in the event of future competition, always favorably looked upon by the public, the road with the most advantageous location will get the most of the traffic.

A line to be a good commercial route connecting various towns can seldom be located in a way that will exemplify ideal physical location. Hence the average engineer has to fight against the tendency to select the route giving the most favorable grades and curves at a minimum cost, his training being along those lines. He must err, if necessary, on the other side, and at probably a greater first cost to sub-grade, get a line that from the commercial point of view is superior.

Some railroad manager has said that railroad engineers seldom think above sub-grade, and give comparatively little thought to the operating maintenance and commercial aspects of the problem This however is hardly correct with reference to the maintenance, but to a large extent holds for the commercial view and is due no doubt to the training of the engineer at college, and possibly for some years following. I have made these remarks to impress the fact, often lost sight of, that a railway is a commercial enterprise and is constructed solely for profit and not to benefit the health of the promoters.

After the engineer has secured all data possible from maps and local sources, he is prepared to start out on his reconnaissance to select a general route between terminals, and sometimes the terminals themselves. This survey, best made on foot, is usually over an area between terminals through which the proposed railroad must pass, and will be of such a nature that he will be able to eliminate several possible routes and restrict the future instrumental work to two or three lines. The engineer must know the country over a wide area between these terminals so that he may himself be satisfied that he has selected the best route or routes. Too great haste in doing this work, often arduous, will mean that he will probably require more instrumental survey later.

There is a practice followed by one or two prominent roads which places one engineer on the route upon reconnaissance, another upon preliminary, and a third following upon the location. This is a most reprehensible practice, for no quantity of notes or topography can take the place of an intimate personal knowledge of the problems to be encountered. For this reason the reconnaissance and preliminary should be made by the engineer who is to locate the road. Of course where the survey is for a great distance or to be made in great haste, the former method will probably be adopted. but with the almost inevitable result that the preliminary engineer, and later, the locating engineer, will follow like sheep along the line laid down by the reconnaissance engineer. Unless very exceptional men are in charge of these parties, with less hurrying than is now the practice, the above may be looked for.

It is a well known fact that the most glaring mistakes in location are generally found upon the prairies due either to this practice or laziness on the part of the engineer. If the reconnaissance is to be through a heavily wooded part of the country then the engineer should provide himself with the following instruments which he will find of great convenience, although he may get on without some of them: two pocket barometers, field glass with level attachment, pocket compass and a pedometer that will give approximately the distance covered each day or between known points. A guide should be engaged, one who thinks he knows the whole country and upon whom you can depend to pilot you along the best trails. But it has been the writer's experience that these guides know very little about relative elevations and will probably consider country dead level which will rise or fall on one or two per cent. grades. This is of course a natural defect that must be expected, as probably before you had arrived upon the scene they had never any call upon this kind of knowledge. In regard to horizontal distances, however, these men are generally more reliable. In any event the engineer must not take anything for granted, but prove everything. If the reconnaissance is through an open or farming country, then he may take it for granted that every farmer will carefully point out to him that there is a much better location for a railroad along a certain valley about a mile or two away. The country is full of these amateur locating engineers and they are always heard from.

The reconnaissance engineer should be a man who has had considerable experience in locating and upon construction, for this work requires a higher order of mind than is called for in merely running a line in detail by the use of instruments. The maintenance and operating will depend upon the reconnaissance, and this most important part of the survey should be entrusted only to engineers of proven ability. This is well understood by the older roads, but is nearly always lost sight of upon new roads under new management.

It is an unfortunate habit still in existence, to hurry the reconnaissance survey, and later location survey, with the result that the best line is not always secured. Money spent on thorough surveys is well spent and the older railway managements recognize this. Probably one of the most glaring cases on record happened in Northern Ontario, where a certain road was built fifteen miles into a *cul-de-sac,* all of which had to be abandoned. The reconnaissance engineer should be of sanguine temperament, one who always takes it for granted that no matter how difficult the country may appear, he can find a good line through it.

The first question to decide is what are the controlling points, such as the lowest point in a ridge or mountain, the crossings of large streams or the location of a town through which the road must be built. Once these are secured and noted upon his map, he can decide upon his limiting grades and curvature. He will then have to go carefully over the ground examining the section of country likely to suit these grades or curves.

The ground should be gone over from both directions, as it often has a different appearance when approached from different quarters. Do not adopt too high a maximum grade, as low grades are the most important of all the details, and the cry on all the older roads is now grade reduction. The most troublesome country through which to locate a line is an irregular rolling country having hills and valleys trending in different directions, and it requires a tremendous lot of hard work before the engineer is satisfied that he has about the best line. There are too many possible lines through this kind of country, and it is here that the experienced engineer will do his best work. Along shores of rivers or lakes there is little or no difficulty, providing the topography taken later on upon locations is accurate. Upon this I will touch further on.

There are some ocular illusions that must be guarded against. For instance, when looking toward a hill the intervening ground will appear level or falling, whereas it is rising toward the hill. Hills at a distance and overlapping will have the appearance of forming a solid ridge and many errors have been made through this cause. A slope will appear steeper than it really is if the observer be looking down it. Heights and distances are estimated more closely on cloudy days, and it should be remembered that distances are less than they appear to be if the observer be looking toward the setting sun.

When the engineer has decided upon the route or routes over which to run preliminaries and has his map marked with all necessary information, he is ready to organize his party for the preliminary survey. The field corps for a preliminary survey on the best roads is now composed of chief, topographer, with his rodman and tapeman, transitmen, leveller, draughtsman, rodman, front and rear chainmen, picketmen, cook, and if in heavily wooded country, about five or six axemen. The day has passed, on the larger roads at all events, when the chief is expected to act as his own draughtsman, and it is quite time that it has. If he has been on the line all day directing the party, he is seldom in fit condition to work over a draughting board for several hours every evening. The chief of party, according to some engineering handbooks, should possess so many qualities that if he had them he would not be in charge of a survey party. He should however know how to handle men, have a knowledge of construction as well as location, and in settled districts know enough to keep to himself, for obvious reasons, the location of the road and stations.

There is a growing feeling among railway engineers that next to the chief of party on preliminary surveys, the first assistant should be the topographer. The transitman's duties are really not of a very intricate nature, for he simply takes notes of the angles, distances and bearings, as you all know, but a good topographer must know about as much as the chief about the line if he is going to take intelligent topography, especially if the country be very broken. A common error in this work, especially along steep side hills, is not to go far enough out in the deep holes or high enough upon prominent points. It is the cause of much profanity on the part of the chief to find that the topographer stops short just where he needs information concerning some gully or adjacent hill. It may be that he wished to throw his proposed location line on the high ground in order to get material to fill the gully. Later on during location, if this topographer be inaccurate, more time will be wasted re-running lines than would have paid for two topographers. By the usual methods of checking, the transitman and leveller seldom make errors that are not quickly found, but the topographer has the chief at his mercy until the line is run over the topography taken upon the preliminary. Five hundred feet on each side of the line in 5-foot contours should be taken in comparatively level country, but upon sidehill the matter lies with the judgment of the chief of party or topographer, if he has any.

These contours are best sketched directly into a notebook divided into squares each representing a hundred feet and having the centre line down the middle of the book. This method will be found more accurate than by noting distances out right and left with elevations. A hand-level properly handled will give good results, and with the assistance of rodman and tapeman a good topographer should not have any trouble in keeping close to the level party from whom he can get his elevations.

The duties of the transitman, leveller, draughtsman and chainman are well known. The picketman should also be a good axeman to make quickly the hubs, hub-stakes, back-pickets or cross-heads, besides giving line to the axeman. He should also have good judgment in selecting turning points if the chief is not on the line. In the wooded districts it is not at all difficult to get good axemen so far as mere chopping is concerned, but it requires two weeks' training at least to get the idea out of their heads that they are not cutting out wagon roads and to keep them in line. Every unnecessary tree cut down is so much time lost, for the axemen set the pace for the rest of the party. Another fault is that they usually persist in bunching up and do not line out along a distance say of a hundred feet.

If the chief is ahead most of the time then it is wise to pick out the most intelligent axeman and make him head axeman at a slight increase of salary. If the party is travelling at a good rate a "stake artist" is sometimes necessary. He should be selected from among the axemen. In most cases the picketman can cover this work also if he is at all quick on his feet.

The custom of conducting all preliminary surveys with a transit is not always to be recommended. In case of short trial lines a compass should be used, thus saving much chopping and of course much valuable time.

In settled districts or open country the axemen are not necessary, but an extra man may be required as teamster and to distribute stakes. It is not wise to cut up fence rails for stakes or hubs, if you wish to keep on friendly terms with the local inhabitants or lessen the troubles of the agent who will later purchase the right-of-way.

This staff I have mentioned is a large one, but necessary if the plans are to be kept up to date. The methods followed at the time of the building of the Canadian Pacific Railway and the attendant hardships are no longer necessary in this country unless several hundred miles from the nearest railway. Some of the older generation of engineers yet think it necessary to make martyrs of themselves in a manner that members of no other profession would dream of doing. But the day of the rough and ready man has passed in this country. The engineer has a right to as much comfort and assistance as he may think necessary, and the results will be that the standard of his work will be much superior in every way than if he tried to do too much and put up with unnecessary hardships. It is not very many years since a topographer was considered necessary, and still fewer, a draughtsman. That the addition of these extra members to the survey party has been a great success both financially and in the amount of work returned, will be conceded I think by every railway engineer.

About 40 feet of one and one-half inch ($1\frac{1}{2}''$) gas pipe in sections of ten feet with one end pointed, should be carried along to test the depth of swamps, proposed crossings of rivers and along the shores of lakes where the embankments may overlie rock at a steep inclination. In this latter case, it is better to shift the line than to take chances upon the possibility of the embankment doing so later on. These soundings can be taken by the leveller and his rodman without much interference with their regular work.

After the engineer has finished his preliminary surveys and has decided upon the best line, he is now ready to begin his location on his plans of preliminaries which, by the way, in order to avoid cumulative errors, should be laid out by the method known as "Latitudes and Departures." He will by this time have projected a paper location and from the contours secured his profile and estimate of quantities. During the survey he has noted the nature of the soil, outcroppings of rock, size of streams, timber, ballast material and everything that may come into the consideration of construction, maintenance and operation. From this information he can form an intelligent idea of the relative values of the different routes. The projected locations will show the lines with curves approximated, and the profile will have grades duly compensated for their curves. If at stations, the compensation should be one-tenth of one per cent. per degree of curve. At other places four-hundredths of one per cent. per degree of curve.

Reversed curves should never be used, but should have, if possible, three hundred feet between transition points. "Broken back" curves also are generally unnecessary, and curves in the same directions should have about three hundred feet between transition points.

Trackmen find difficulty in keeping a one degree curve in line, and a sharper and shorter curve is preferable. A curve should not be less than three hundred feet in length. It is an undecided question with engineers as to which is the better method within certain limitations, that is, whether to put in short tangents and flat curves or longer tangents and sharper curves, the limit of the length of curve being 2,000 feet. Personally, I favor the longer tangent and sharper curve up to six degrees. Curves of three degrees and over should have transitions to the tangents at both ends. In the following table are given the essentials for spirals for chord lengths of 60 feet for curves up to six degrees. Dividing by two will give data for 30 ft. chords or for rail length chords. The table requires no explanation and is of convenient form to paste in the back of a transit book.

Spiral Table

Curve.	Length of Spiral	No of Chords	Length of Chords	Total Angle of Spiral	Deflections B.S. to B.C.						Deflections E.C.T. E.S					
1° 0'	60'	1	60'	18"	06'						12'					
1°30'	90'	1½	60'	40½"	06'	13'					12'	27'				
2°0'	120'	2	60'	1°12'	06'	24'					30'	48'				
2°30'	150'	2½	60'	1°52½'	06'	24'	37½'				21'	54'	1°15'			
3°0'	180'	3	60'	2°42'	06'	24'	54'				48'	1°24'	1°48'			
3°30'	210	3½	60'	3°40½'	06'	24'	54'	1°13½'			30'	1°21'	2°00'	2°27'		
4°0'	240'	4	60'	4°48'	06'	24'	54'	1°36'			1°06'	2°00'	2°42'	3°12'		
4°30'	270'	4½	60'	6°04½'	06'	24'	54'	1°36'	2°01½'		39'	1°48'	2°48'	3°30'	4°03'	
5°0'	300'	5	60'	7°30'	06'	24'	54'	1°36'	2°04'	2°45'	1°24'	2°36'	3°36'	4°24'	5°00'	
5°30'	300'	5½	54½	8°15'	05'	20'	45'	1°36'	2°04'	2°45'	43½'	2°04'	3°13'	4°14'	5°04'	5°30'
6°0'	300'	6	50	9°00'	05'	20'	45	1°20'	2°05'	3°00'	1°25'	2°40'	3°45'	4°40	5°25'	6°00'

On location the transitman's duties will increase, for he will now have the curves to calculate and run in. If in bush country, the method of long chords will be used. The transitions will be located by offsetting.

The notes for the location are calculated from and should not be scaled off the projected paper location. This is where the topographer shows how accurately he has done his work, for, assuming that he has transferred the notes correctly to his note-book, then the profile secured should approximate very closely to that obtained from the projected location. If you are fortunate in your topographer it generally will, and you will lead a contented life. Otherwise no one should wonder why engineers are such profane men.

On comparatively flat ground or rolling ground, the excavations and embankments may balance fairly well. On prairie, the grade will generally be above the ground a couple of feet, on account of drifting snow, the material being taken from the side ditches. On side hills, especially where it is steep, the profile will be delusion so far as quantities are concerned.

There is always the temptation with an engineer inexperienced in construction work, to locate the line so as to show a well balanced profile along steep side hills. The practice of promoting the transitman to chief of party as the next logical step in advance, regardless of his possible lack of knowledge of construction, generally results in a location which though looking well on paper, cannot be built except at a cost far beyond the probable estimate.

The slopes of the embankments may run out into a river; a creek may enter a river at the crossing so close to centre line that the creek will have to be diverted, possibly at great cost. Two creeks may converge into one just at centre line, so that a culvert built will project some distance up one creek (if embankment be high). This will necessitate the removal of the ridge between in order to divert the second creek. The location may be through a swamp where no suitable material for filling can be secured for miles, or where the line cannot be drained except by building ditches sometimes great distances, and where by a change of line and grade all this would not be necessary.

In low lying sections of country the principal thing to be considered is the drainage of the roadbed and the removal of the water from the right-of-way as quickly as possible. This question of drainage is too often overlooked in the location of a railroad.

The locating engineer should carefully estimate the sizes of culverts and openings required, and not leave this to the transitman or topographer, as is often the case. The contractor may give a price for culverts say of 10 feet span at several openings, and refuse to go ahead on the work, and with good reason, when he finds the construction engineer has reduced these to say 4 feet span. It may not be worth the cost of bringing in his plant. In all fairness the engineer cannot hold him at the same price for say, hundreds of yards of concrete, when he had figured on thousands.

So important has the location of the line become, both as to initial cost and operating, that some roads, notably the Transcontinental (G. T. P. Ry.), have three locations, first, revised and final, made under three different engineers. That it pays to run a revised location under a different engineer has I think been proven, and the extra cost of survey has been more than paid for in every case. The value of the third or final location is doubtful in some sections anyway, and not worth the cost in others, providing the first two have been made under competent men.

Upon the profile should be noted the estimate to sub-grade for each mile as common excavation, loose rock, solid rock, borrow, overhaul, masonry, timber, rip-rap, bridges, and in fact everything to get a close estimate. To the estimated quantities ten or fifteen per cent. should be added, which should give a closer approximation to the correct quantities. At summits or depressions where the grades change, it is important that these changes be made by means of a vertical curve of such length as will allow the longest train to pass from one grade to the other without the cars piling up against each other. With the present equipment, this rate of change should not be greater than one-tenth of a foot per station in depressions and three-tenths of a foot per station on summits.

The use of " momentum " grades is not to be recommended in this country except under very exceptional conditions. The climatic conditions combined with snow may reduce the speed at the bottom of a grade to such an extent that the train will be " stalled " before reaching the top.

The three factors to be considered in comparing two lines (outside of commercial possibilities) are distance, rise and fall, and curvature. Where distance is less than two miles, or so short as not to affect train or track wages, the justifiable expenditure per mile in saving of distance for one daily train per annum is $2,600 at present rate of interest. Where distance affects train wages, but not so great as to affect the number of stations or sidings (from 2 to 5 miles), the justifiable expenditure is $4,500. Where distance is so great as to affect the number of stations and sidings required (from 5 to 75 miles), the justifiable expenditure is $5,300.

With regard to rise and fall, the justifiable expenditure for one foot per daily train per annum will be $3; up to rise or fall of thirty feet $12 where grades require steam to be shut off, but not the application of brakes in descending. Where rise or fall over thirty feet on grades is less than 0.6 per cent. grade, and between thirty and one hundred feet on 0.6 per cent. grade, $22. This is assuming a maximum freight train speed of 30 miles per hour and the minimum of 10 miles per hour.

The elimination of one degree of curvature (central angle) will save 16 cents per daily train per annum.

Level crossings of other railways are always to be avoided on account of the cost of maintenance, and would justify an expenditure of $40,000. It is very doubtful if the Railway Commission would allow a level crossing in this country now. The above amounts are not to sub-grade only, but include ballast, ties, rails, etc.

In conclusion, I desire to say that the preceding notes, with the exception of train costs, will apply to electric as well as to steam railroads, although this paper was written with reference principally to steam roads.

PRODUCER GAS FOR POWER.

S. L. Fear, '06.

RIVALLED ONLY BY WATER POWER UNDER THE MOST FAVORABLE CONDITIONS.

The necessity for cheap power to the manufacturer, in these days of such keen competition, when he must get as large returns as possible from every cent expended, is one of the engineering problems of the twentieth century.

Necessity is surely the mother of invention, and with the necessity has come the invention. During the past few years the manufacturer has turned with interest and profit from the steam boiler and engine, with their numerous auxiliaries and low efficiency, to the gas producer and gas engine, since in these he finds a more compact and simpler plant, having a higher efficiency. He also finds his expense bill a great deal smaller at the end of the year.

The introduction of the suction gas producer came with the demand for a small compact gas producing plant to be used in connection with the gas engine. This demand was first realized and brought into practical application by the Germans and French about twenty-five years ago, but was rapidly followed up by the English and Americans. To-day, because of the efforts of these engineers, the suction producer gas plant is finding favor with the layman, the engineer, and the manufacturer, as the best means of obtaining maximum energy from cheap fuel.

Investigating the efficiency of the two classes of plants, both using coal and water as their sources of energy, we will find that the efficiency in the best regulated steam boilers and engines rarely exceeds 14 per cent., and this efficiency depends not only on the type and size of the engine, but to a large extent on the auxiliaries, such as condensers, pumps, separators and economizers, without the use of which the efficiency often falls to 6 and even 3 per cent., which are common figures for non-condensing plants. If in place of the boiler we put a gas producer, and in place of the steam engine and auxiliaries we put a gas engine, an efficiency of 20 per cent. is commonly attained, even in small plants, and the tendency in larger powers and later developments is toward higher efficiencies yet, 24 having been obtained. Table I. gives an average of efficiencies of steam plants using the different types of engines, the coal used being assumed to have a heating power of 13,000 B.T.U. per pound. Table II. gives the efficiencies of the different gas engines connected to gas producers, from actual tests.

TABLE I.

Type	Pounds of Coal per B.H.P.	Thermal Efficiency (%)
Simple non-condensing—		
Throttling	6	3.26
Automatic	$4\frac{1}{2}$	4.35
Corliss	$3\frac{1}{2}$	5.6
Compound non-condensing—		
Corliss	3	6.55
Compound condensing—		
Corliss	$2\frac{1}{4}$	8.75
Steam turbine condensing	$1\frac{3}{4}$	11.25
Triple condensing Corliss	$1\frac{1}{3}$	14.75

TABLE II.

B.H.P.	Type	Fuel.	B.T.U. Fuel, per pound	Fuel in lbs. per B.H.P.	Thermal Efficiency (%)
20	Single cylinder,	anthracite	15,138	0.797	21.25
90	Single cylinder,	coke	12,411	0.910	22.5
250	Double acting,	anthracite	14,600	0.744	23.3
300	Two-cylinder,	anthracite	11,370	0.975	24.0

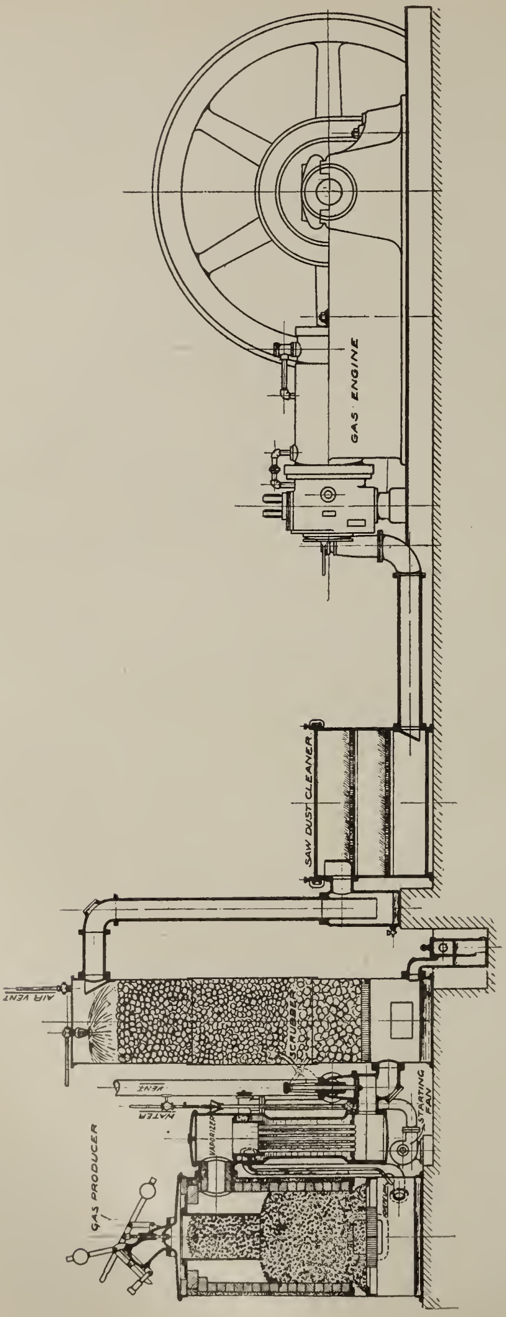

GAS ENGINE
SAW DUST CLEANER
AIR VENT
SCRUBBER
VENT
WATER
VAPORIZER
GAS PRODUCER
STARTING FAN

FIG. 1.

But why such high efficiencies? Well, let us look into the construction of a suction gas plant, and then we may be able to compare it with the steam plant, which is now so thoroughly understood. The main parts to the producer plant are generator, vaporizer, scrubber and equalizing tank. We shall take these up in order.

The Generator.—Figure 1 shows a cross-sectional view of an entire plant (Koerting). To the left is seen the generator. As will be seen, it is cylindrical in shape. The shell is made of steel plate to allow for expansion and contraction that takes place in operation, which contraction and expansion would soon destroy cast iron. Here the base is, also, made of steel plate, but is preferably made of cast iron, which is better suited to resist corrosion. Inside the steel shell, supported by the base, is a lining of brick. These bricks are quite often made of fire clay, but when made of silica will last longer. In a plant of 100 H.P. these bricks should not be less than 8 inches deep. Between the walls and the brick lining, ashes are usually placed to prevent loss by radiation. The usual style of fire grate as used in steam practice is placed in the base to support the coal. The grates are supported by the base, and are so arranged that they may be shaken by a lever outside the base. Doors are provided in the base and lower part of the generator proper, also poke-holes in the top, for the purpose of breaking clinkers in the fire and removing clinker from the bricks. A water seal is formed at the bottom by keeping water in the base up to a constant level. The top is usually flat, except for the coal-feeding apparatus, which is of several different shapes. The idea of all types is to feed the fuel to the generator, and not allow air to enter while feeding. For this purpose there are two joints, with a chamber between, which joints may be opened or closed, one independently of the other. The fuel is fed through the first opening into the chamber, the second opening being closed. The first is then closed and the second opened and the fuel drops into the generator without its being opened to the atmosphere. The air and steam, for combustion of the fuel and the formation of the gas, are brought to the grate through the base by a pipe from the vaporizer.

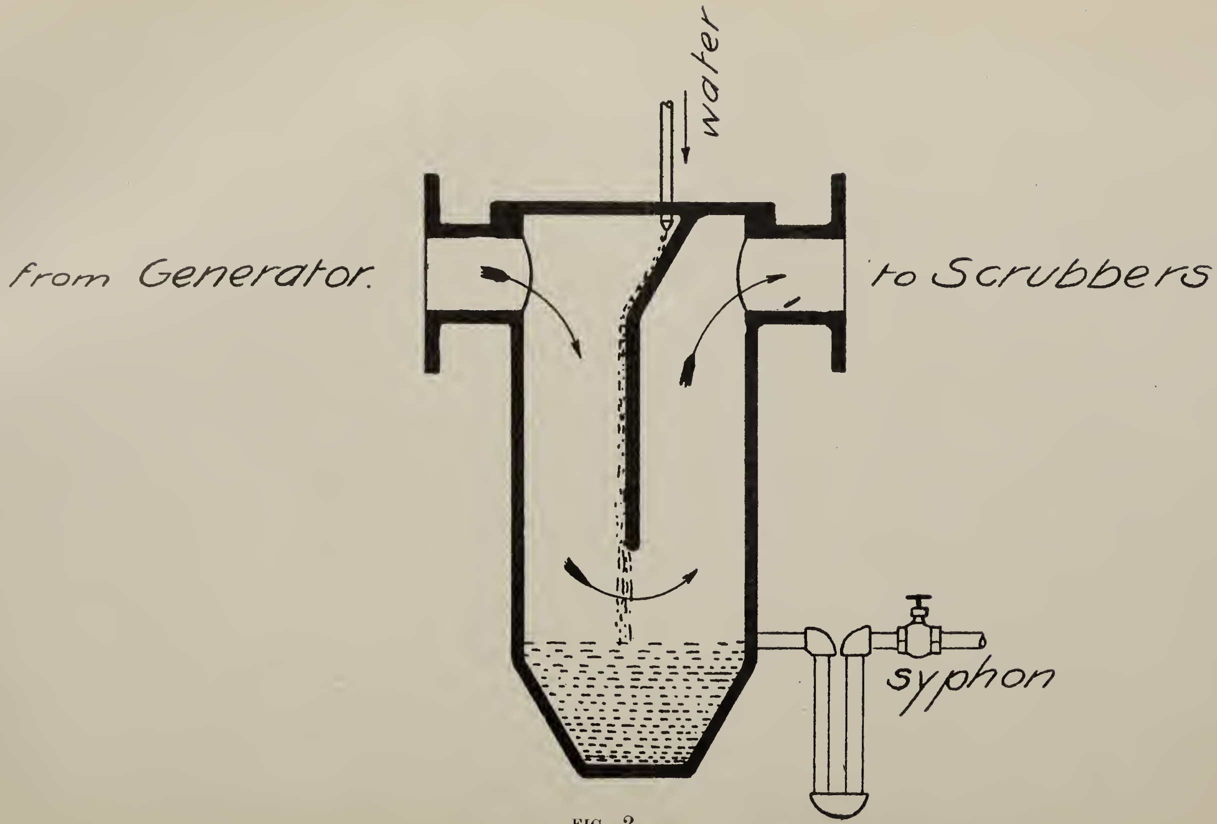


FIG. 2.

The gas at a high temperature is drawn from the generator into the vaporizer. The vaporizer serves a two-fold purpose—to cool the fresh hot gases and to supply steam for the formation of the gas. In some cases the vaporizer is placed at the top of the generator. Where the maker wishes economy by keeping as much heat as possible in the generator, and consequently less heat will be abstracted from the coal for combustion, the vaporizer is placed outside the generator in the shape of a small tubular boiler. The gases pass down through the tubes and give up to the water surrounding them a great deal of their heat, thereby changing the water into steam. Some makers have used a vaporizer in the top of the generator and a superheater outside. Why not use the generator outside and a separate superheater, which would be heated from the exhaust gases from the engine? An opening in one side of the vaporizer is arranged for the admission of the air from the other side, a pipe carries the air and steam to the generator. The level of the water is kept constant by a syphon.

The gas then passes into the scrubbers through the valves shown, which valve or valves are so arranged that the generator may either be connected with the scrubbers or the atmosphere. For this purpose two independent valves may be used, or a valve with a water seal, as shown in Figure 2. This seal is formed by closing the valve in the syphon, thus causing the water to rise in the chamber and stop the passage of gas to the scrubbers.

The scrubbers are tall cylindrical chambers. Their purpose is to clean and cool the gas. They are fitted with either wooden slats crossed and staggered or with coke or charcoal. The coke or charcoal is graded—coarse where the gas enters; fine where it leaves. But whatever is used, water is continually sprayed over the top layers and passes down through the wood or coke, cooling the gas and cleansing it by absorbing the dust. Quite often there is a dry cleaner placed either at the top or at the side of the wet scrubber. The dry cleaner is filled with sawdust, excelsior and shavings, which absorb the moisture from the gas. At the bottom the water which drips from the filtering or cleansing material is allowed to collect and kept at a constant level by a syphon, thus forming a water seal.

Since the production of the gas depends on the suction of the engine, and since this suction is not uniform, especially in a single-cylinder four-cycle engine, an equalizing tank is placed between the scrubber and the engine. This tank is just a chamber of several times the volume of the engine cylinder, and because of this furnishes a good full cylinder of gas to the engine on the suction stroke, since, between suction strokes, the tank fills again because of the vacuum produced.

Let us consider the action that occurs in the plant from the time the coal is fed into the generator until the gas is used in the engine. Air and steam are drawn into the generator from the vaporizer and up through the incandescent fuel bed. When they enter the fuel bed carbon dioxide is formed.

$$C + O_2 = CO_2$$

The carbon of the fuel unites with the oxygen of the air. As the CO_2 passes up, an excess of carbon is added and the oxygen having been used up the carbon dioxide becomes carbon monoxide,

$$CO_2 + C = 2\,CO.$$

But since air and steam were both added there is another reaction. The steam has served a two-fold purpose. First, it reduces the temperature of the fuel bed, and thereby keeps clinkers from forming; secondly, it furnishes oxygen without the presence of nitrogen. Then since the steam breaks up into its component parts hydrogen and oxygen, it enriches the gas by the addition of the hydrogen, and by supplying oxygen to the carbon of the fuel without the presence of the neutral nitrogen. The two reactions taking place are as follows:

$$H_2O + C = CO + H_2 \qquad (1)$$

$$2\,H_2O + C = CO_2 + 2\,H_2 \qquad (2)$$

The first is effected by high temperatures; the second by the low temperatures of the fuel bed.

In operating, a fire is kindled upon the grate and the fuel bed is built up in the usual manner, while the necessary air is supplied by a hand or belt-driven fan. The products of combustion escape beyond the vaporizer through a suitably arranged waste pipe. As soon as good gas is produced, as shown at a test cock, the scrubber and purifier are brought into the gas circuit and the whole apparatus filled with gas. When good gas appears at the engine test cock, the engine is put in operation and the air fan stopped, its function being performed thereafter by the engine.

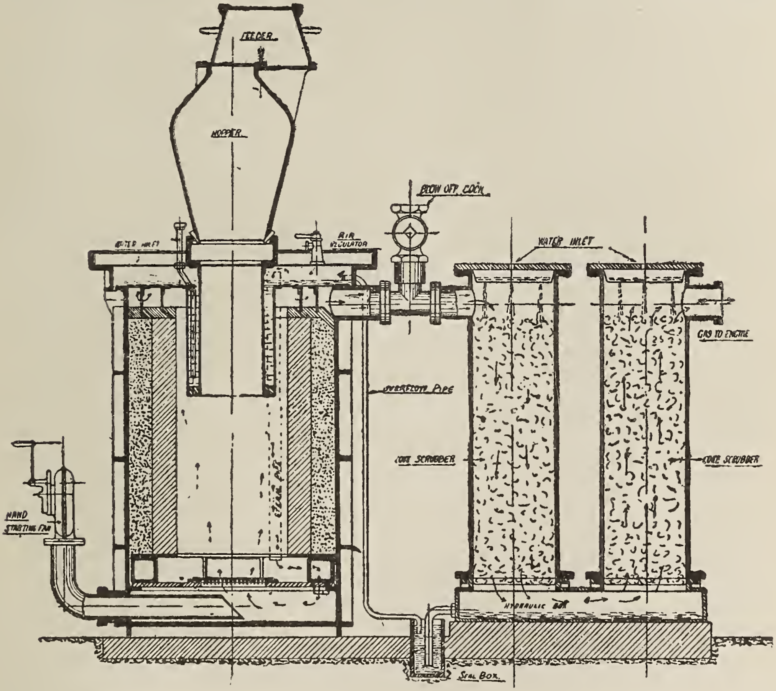


FIG. 3.

A comparison of the cost of operating between steam and gas may be made from Tables III. and IV., which are taken from two English plants of the same capacity, under the same management, having the same capital cost, but separated by about one mile. The first takes the lighting load; the second the power load.

TABLE III.

GUERNSEY STEAM AND GAS-DRIVEN ELECTRIC STATION.

COST OF WORKING, 1905.

	Steam Plant. Lighting Load. Per Unit Generated.	Gas Plant. Power Load. Per Unit Generated.
Coal, including steam pumps, air pump, forced draught at steam station	.436	.200
Oil, waste, water, stores	.037	.042
Wages	.214	.133
Average hours of attendance to run plant when necessary, per day	18	13
Repairs — Buildings, machinery, transformers, main accumulators	.250	.123
Total works costs	.937	.498
Units generated	500.43	718.858
Average per cent. of full load at which engines were loaded during the time of running	68½%	86¼%
Coal used per unit generated	4.97 lbs.	2.21 lbs.
Price of coal in bunkers—Washed anthracite peas used at each station	16s. 2d.	15s. 6d.

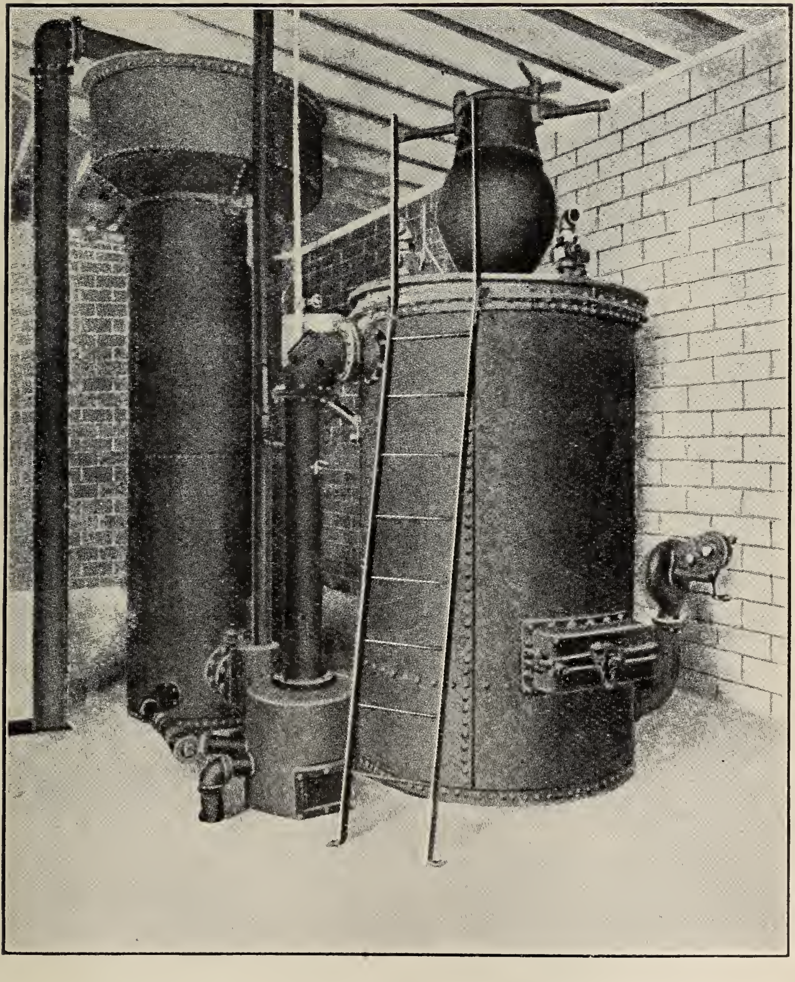


FIG. 4.

TABLE IV.

GUERNSEY STEAM AND GAS-DRIVEN ELECTRIC STATION.
COST OF WORKING, JANUARY TO MARCH, 1906.

	Steam Plant. Lighting Load. Per Unit Generated.	Gas Plant. Power Load. Per Unit Generated.
Coal, as in Table III	.391	.151
Oil, etc., " "	.027	.046
Wages, " "	.209	.136
Repairs, " "	.207	.176
Total works costs	.834	.509
Units generated	164,323	162,438
Price of coal in bunkers	16s. 2d.	15s. 6d.

A cost of operating a gas plant for a month may be had from Table V.

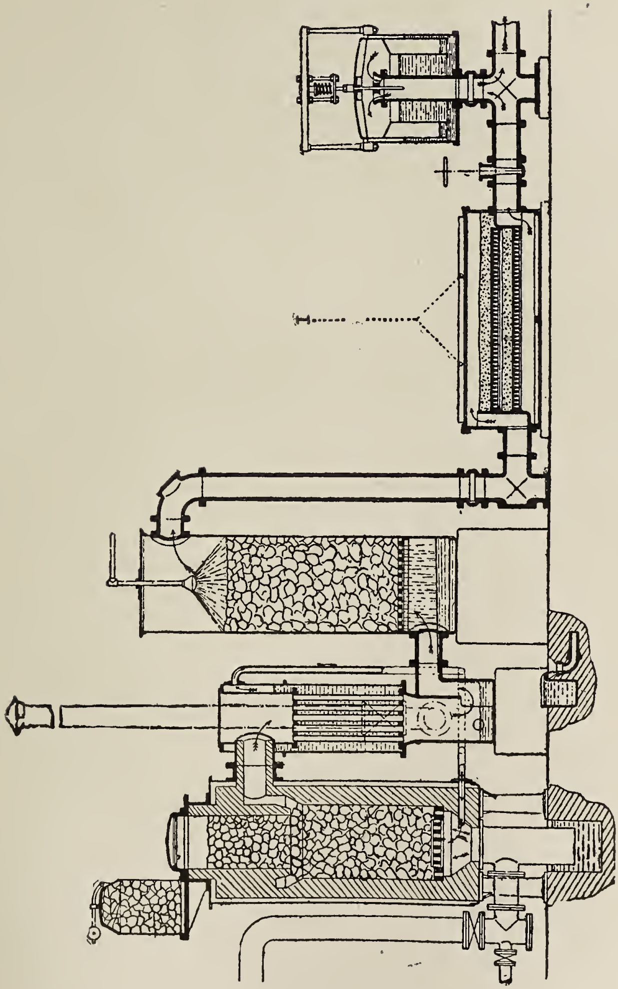


FIG. 5.

TABLE V.

COST OF WORKING BROXBURN ELECTRIC POWER STATION FOR OCTOBER, 1906.

Twenty-nine Working Days.

Total fuel consumed	6 tons 13 cwt.
Total units generated	6917.
Duration of run per day	7½ hours.
Units generated per day	231.
Consumption of fuel per hour	69 lbs.
Units generated per hour	33.
Consumption of fuel per B.H.P. per hour	1·25 lbs.
Cost of fuel per B.H.P. per hour	·08d.
Consumption of fuel per unit	2·09 lbs.
Cost of fuel per unit	138d.
Consumption of oil	10 gallons.
Cost of oil per gallon	2s. 3d.
Cost of 20 B.H.P.	1·6d.
Cost of fuel in bunker	12s. per ton.

From this table one may see that the stand-by losses have been included. (By stand-by losses in the suction gas plant we mean the amount of coal consumed to keep the fire alight from the time the engine is shut down to the time of starting again.) In Tables VI. and VII. a comparison of these stand-by losses may be made between steam plants and gas plants.

TABLE VI.

CONSUMPTION OF FUEL IN STEAM BOILERS IN STANDBY HOURS.

	Type of Boiler	Max. H.P. of Boiler	Coal consumed per standing hour	Authority
1.	Various	100	14·0 lbs.	Mr. Deely, Loco.-Supt., Midland Railway
2.	Lancashire ...	450	*37·5 "	Mr. Henry Lea
3.	Babcock & Wilcox	210	67·0 "	Col. R. E. B. Crompton
4.	" "	210	67·0 "	" " "
5.	" "	500	180·0 "	Mr. H. Collins Bishop
6.	" "	500	112·0 "	" " "
7.	Niclaussé ...	400	50·0 "	Messrs. Willans & Robinson
8.	Lancashire ...	400	44·7 "	Mr. F. A. Wilkinson
		Average	71·5 lbs.	

* Exclusive of raising the steam pressure from 90 to 120 lbs.

TABLE VII.

CONSUMPTION OF FUEL IN GAS PLANT IN STANDBY HOURS

	Locality	Max. H.P. of Producer	Coal consumed per standing hour	Authority
1.	Openshaw ...	250	5·1 lbs.	Messrs. Crossley Bros., Ltd.
2.	" ...	250	3·9 "	" " "
3.	Leicester ...	100	2·1 "	Mr. Deeley (Midland Rail.)
4.	Smallheath ...	250	4·5 "	Mr. Henry Lea
5.	Limerick ...	225	3·8 "	Mr. J. Enright
6.	Walthamstow ...	375	1·8 "	Mr. F. A. Wilkinson
		Average,	3·5 lbs.	

The cause of this great difference may be explained by the fact that the gas plant is smaller per horse power than the steam. The radiating surface is not so large and steam has not to be raised to a high pressure.

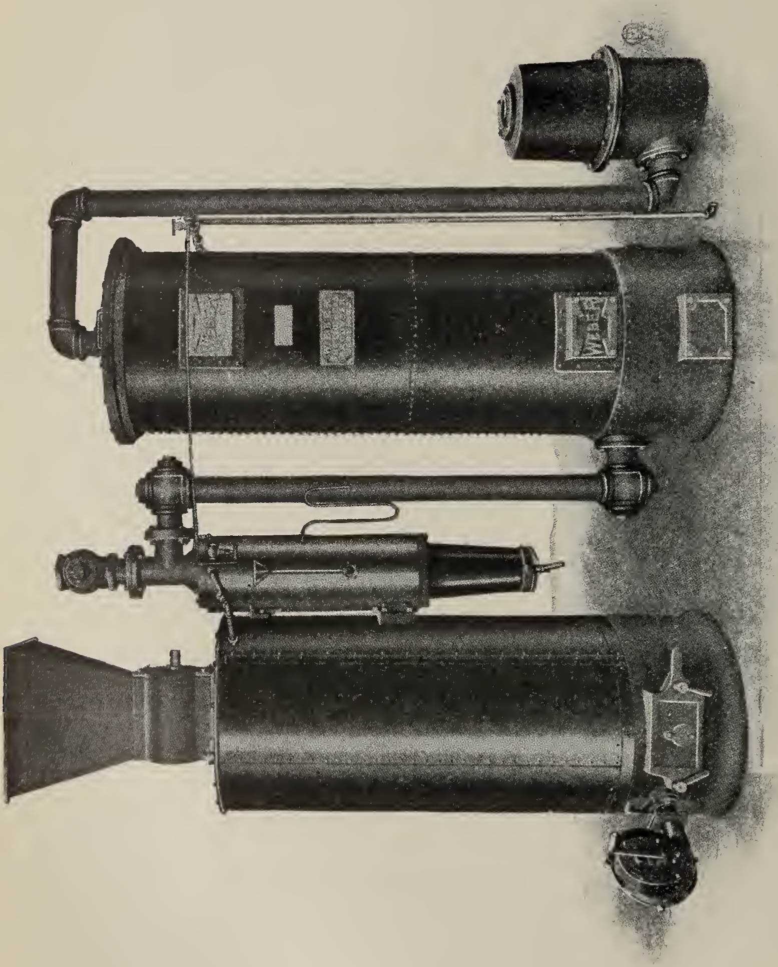


FIG. 6.

Although English and foreign practice may have been ahead of the American, yet the following Table, No. VIII., will show that the American is following very rapidly on the heels of the fathers of the suction gas plant.

Table VIII.

The gas producer was built by the Cone Gas Machine Co., Detroit, Mich. It was rated at 25 H.P. The engine was a Bruce-Meriam-Abbot gas engine, vertical, 8.5″ x 10″ cylinders, and was belted to a 17.5 K.W. 110-volt Triumph generator. In the test a bituminous nut coal from Springfield, Ill., costing $1.75 per ton f.o.b. Chicago, was used, with results as follows:

Pounds of coal per hour, 13.12.
K.W.'s per hour by wattmeter, 14,616.
K.W.'s per hour by volt and ammeter, 13,050.
Electric horse power per hour, 17.4.
Efficiency of dynamo and belt assumed, 80%.
Brake horse power per hour, 21.7.
Pounds of coal per B.H.P. hour, 0.6.

The use of the suction gas plant in marine work, and especially in the navy, is another big field only recently opened. The chief advantages are as follows:

1. A saving in weight of machinery and boilers, which can be applied to other parts of the ship.

2. A saving of labor since the coal can be mechanically dropped into the producer, whereas it must otherwise be shovelled into the furnace of the boiler.

3. The pressure in a producer is below atmospheric pressure, while in a boiler it is a great deal above. The puncturing of a producer by a shell will thus not be nearly as serious a matter as the puncturing a boiler. One producer can be easily cut out in an emer-

gency and those remaining are capable of taking an overload better than a number of steam boilers.

4. A ship having producers cannot be discovered by her smoke —there is none.

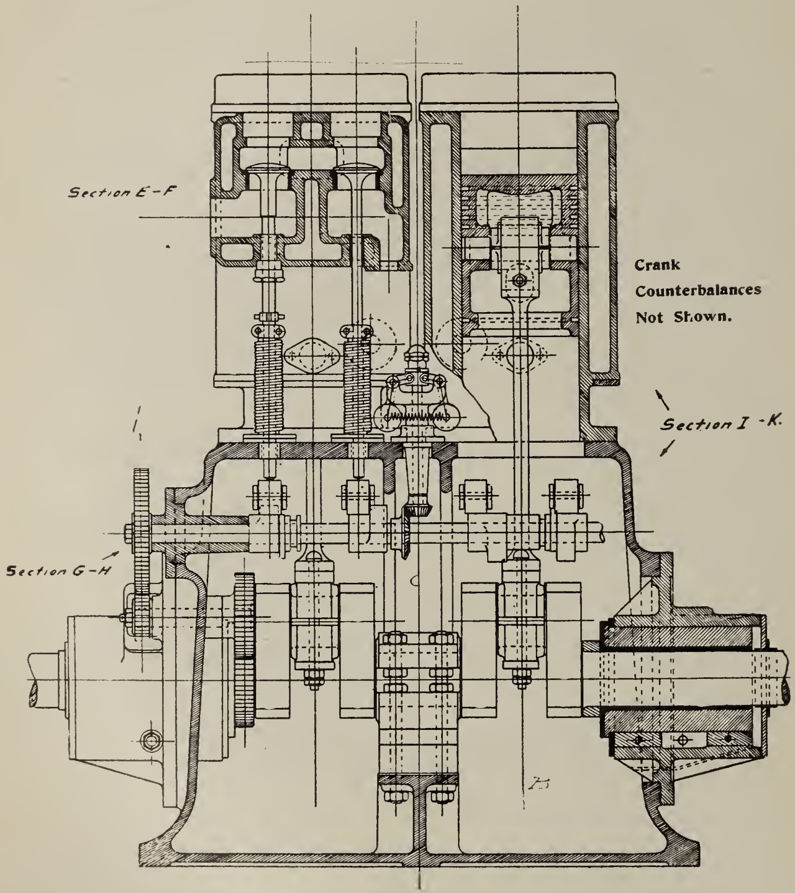


FIG. 7.

The source of energy may be important, but we must have with the source the means of turning the energy into mechanical work. The gas producer as the source has the gas engine as its transformer of energy.

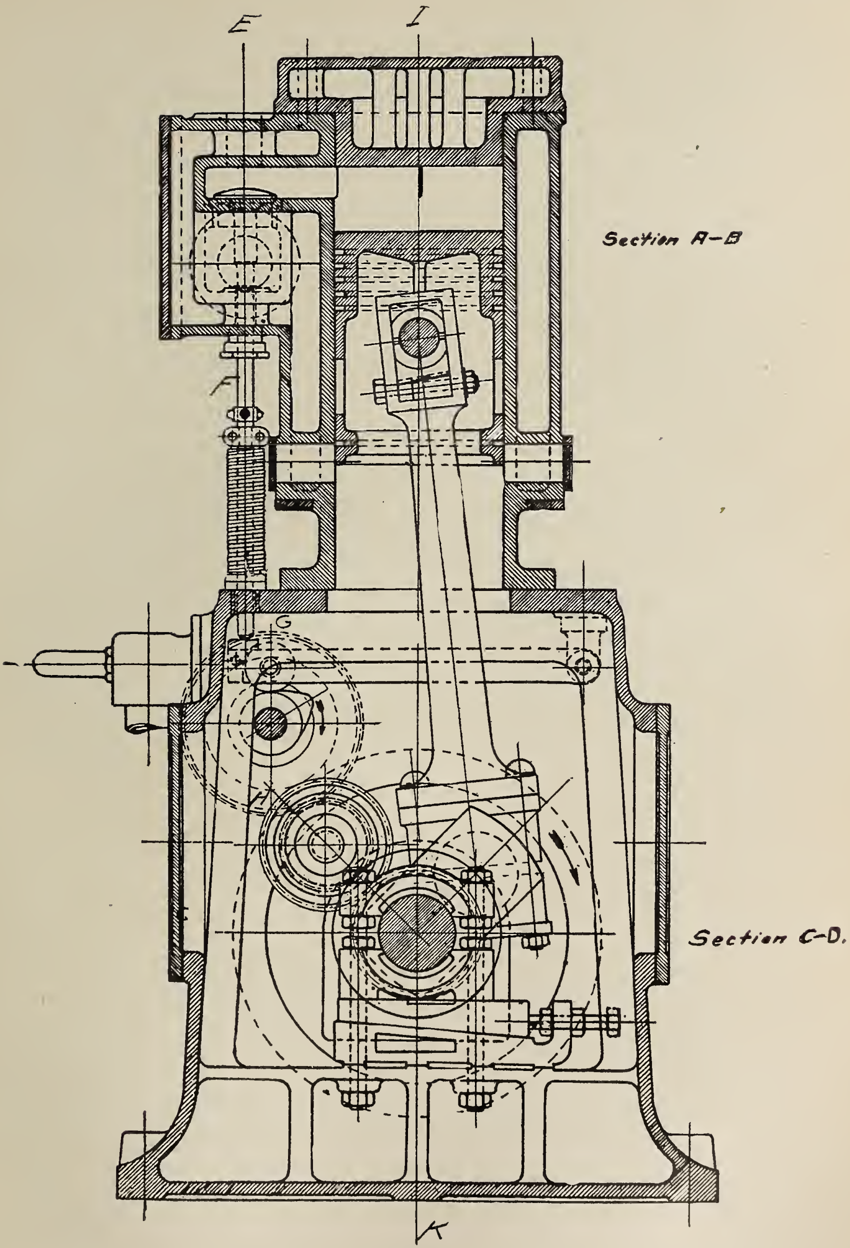


FIG. 8.

It is impossible in this paper to go into the design of gas engines, but in passing it may be said that the compression for producer gas engines average 160 pounds, the exhaust valve is water cooled, and forced lubrication is employed. Figs. 7 and 8 illustrate an American engine in which simplicity, strength and durability have been combined to make one of the most efficient engines on the market. This engine is manufactured by the Weber Gas and Gasoline Engine Co. of Kansas City, Mo., who also manufacture the producer shown in Figure 6.

Figure 3 is a section of the Crossley Producer.
Figure 4 is a view of the Wile Producer.
Figure 5 is a view of the Pintch Producer.

The idea of this paper has been to give a short description of this new method of obtaining energy from coal which is now attracting so much attention. It is hoped that the information will be of some benefit to you who read, but whether manufacturers or power users, do not allow this information to lead you manufacturers to give to the public a guarantee which you are not sure you can back up; or you power-users to demand of the manufacturer things utterly unreasonable and impossible.

THE ELECTRO-METALLURGY OF IRON AND STEEL.

S. Dushman, B.A.

It is not so long ago that the only means used for attaining high temperatures were limited to the furnaces working with blast or the oxy-hydrogen flame. With the development of electrical generating machinery and the utilization of water power for lighting and power purposes, it became apparent that herein lay another resource for obtaining great heat. To Sir William Siemens, the great iron metallurgist of the 19th century, belongs the credit of having been one of the first to see the advantages of electro-thermic processes. But it is only recently that the greatest advance in this work has taken place.

Electricity may be used to produce heat by the following methods:—

1st. The use of the electric arc. The arc light is familiar to everybody as a source of very intense light; but it may also be used as a source of heat. The temperature obtainable by this means has been estimated to be about 3,500°C, and a number of electric furnaces have been invented utilizing this source of heat.

2nd. The heating effect due to the passage of an electric current through a conductor. An example of this is the ordinary incandescent light. The electric current passing through the carbon filament of the lamp causes it to be heated to incandescence. The amount of heat generated in a conductor depends upon its resistance and the amount of current that is passing. In fact the higher the resistance and the greater the current the more heat that is produced. The furnaces built on this principle are of the resistance type.

3rd. By the inductive effect of an alternating current passing in one circuit on a neighboring circuit. This is really another variation of the principle used in a previous type. The induction furnace has as yet a very limited application.

The advantages of these various methods of generating heat are very evident. Firstly, the temperatures attainable are much higher than by the other methods in previous use; thus many reactions which are impossible at relatively lower temperatures can be made possible in the electric furnace, and many products which were unknown before the last few years are now produced in large quantities. Secondly, the electrical energy can be utilized as heat much more efficiently than that from coal, because it is applied to the materials to be heated directly and not through the intermediary of refractory walls. Thirdly, the electric furnace is very compact and much more easily controlled as to temperature and character of product than the ordinary furnace.

The electric furnace industry has been a great boon to the development of metallurgy and applied chemistry. From an appliance that was used merely for the fusion of refractory substances and the attainment of very high temperatures, the electric furnace has become a factor in the processes for which coal or gas has hitherto been used; and the older methods are competing against the newer and more aggressive industry.

In the following paper, I intend to deal with the electric furnace as applied to the metallurgy of iron and steel. The whole subject naturally resolves itself into the solution of the following chief problems:

(1) Processes for producing pig iron and steel from ores.

(2) Processes for producing steel and wrought iron from pig produced either in the electro-thermic or blast furnace process.

(3) Processes for the production of the very infusible alloys of iron with silicon, manganese and chromium.

THE PRODUCTION OF PIG IRON FROM ORES.

As Borchers has remarked in his book: "It must be remembered at the outset that of all metallurgical industries, the blast furnace industry with its process of treating the waste gases produced, has been the most thoroughly worked out. There is no metallurgical furnace which has yet attained so high an energy efficiency. Stress must be laid upon this, in order that the difficulties may be appreciated which the electric furnace must encounter in order to compete with the existing blast furnace."

However, there are many localities in which the older processes are not practicable owing to cost of fuel, one of these localities being northern Ontario, and in order to find out if electro-thermic processes could not be useful there, a commission was appointed by the Canadian Government in 1903, "to proceed to Europe for the purpose of investigating and reporting upon the different electro-thermic processes employed in the smelting of iron ores, and the making of the different classes of steel, now in operation, or in process of development, in Italy, France and Sweden." The report of this commission issued in 1904 forms an almost complete summary of all the electrical processes in use for iron and steel, and I have availed myself to a large extent of the information therein contained.

Before we consider, however, the various methods in use for the electrical reduction of iron ores, it may be worth while to briefly consider the operations that are performed in a blast furnace. In the latter the charge consists of iron ore, coke and a flux consisting either of lime or sand or a mixture of both. The coke contains nearly pure carbon, which combines with the oxygen contained in the iron ore, and thus sets metallic iron free. This iron is then melted by the aid of a heat derived from an extra amount of coke. Thus the latter performs in this case two quite distinct and special functions, one of chemical reduction, and the other in fusing the reduced metal. For instance, in a blast furnace there is usually consumed about one ton of coke per ton of pig iron; the theoretical quantity needed for the reduction is only about one-third that amount, and the rest of the coke is simply used to supply the heat necessary to raise the materials of the charge to the temperature at which the chemical reaction will take place and also to fuse the reduction product. The electrical energy can evidently be used only for the purpose of replacing the last named portion of the coke and not that part which is used for chemical reduction.

By calculation of the thermal energy required for these processes, it has been shown that adding the proper quantity of coke for the chemical reaction alone and utilizing electrical energy to provide the source of heat, it requires 3.8 electrical H.P. hours per kg. of iron, or approximately one-third of a H.P. year for one ton of iron. As the difference between the coke actually consumed in a blast furnace and that theoretically necessary for reduction is about 1,200 lbs. of coke per ton of iron, this can be interpreted thus: Assuming that labor and other charges are the same in the two methods, the electrical will be the cheaper if the cost of one-third of an electrical H.P. year is less than that of 1,200 lbs. of coke. With the latter at $6.00 per ton this limits the cost of electrical power to $10.80 per H.P. year. Thus wherever power costs less than that, the electrical method is the cheaper. Of course, as the price of coke decreases so must that of power, in order to make the processes comparative; and wherever the price of coke is high and power is plentiful the electrical method offers the greatest advantages.

The three important methods used for the extraction of iron from its ores are those of Stassano, Keller and Heroult.

(1) *The Stassano Process.*—The furnace used is of the arc type, and M. Stassano, the inventor, deserves great credit for the perseverance with which he attacked the problem of replacing blast furnaces by an electrical method. The form finally adopted by him is shown in Fig 1. The charge is calculated accurately beforehand from an analysis of the ore, coke and flux used. This is then moulded in the form of briquettes and subjected to the radiation of heat from an electric arc situated above the charge to be heated.

The furnace consists of a cylindrical outward casing of iron surmounted by a conical roof. It is lined with magnesite brick and rotates about an axis, which is slightly inclined to the vertical. A three-phase alternating current of 400 amperes and 90 volts between the phases is distributed to the three electrodes, which nearly meet in the centre of the interior of the furnace. Experiments performed in 1903 showed that the power used in producing iron by this process is about 0.27 electrical H.P. years per ton of iron.

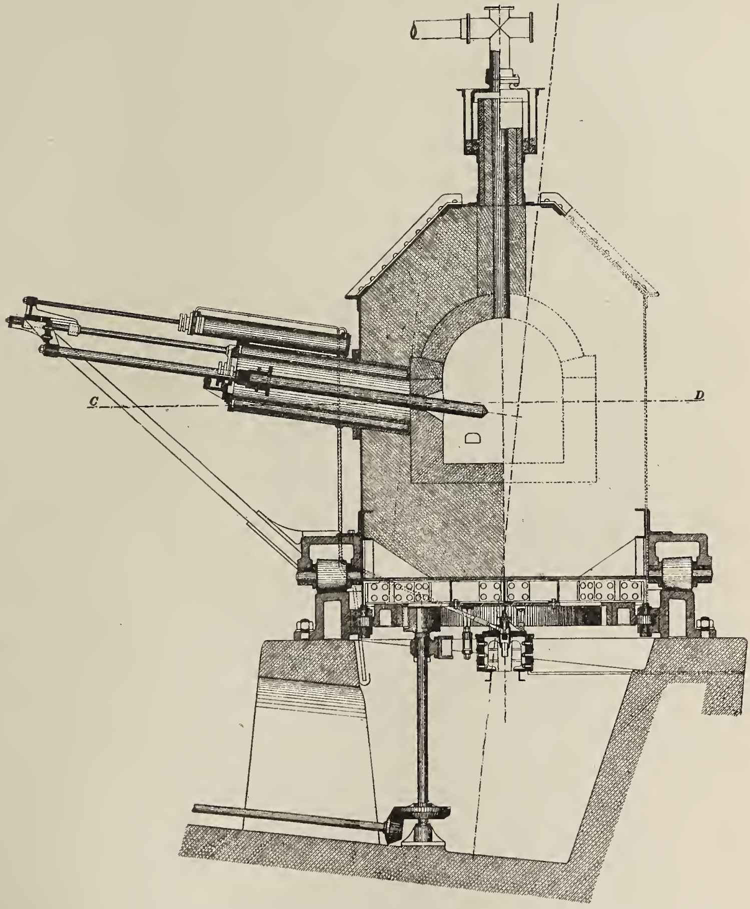


FIG. 1.—STASSANO FURNACE.

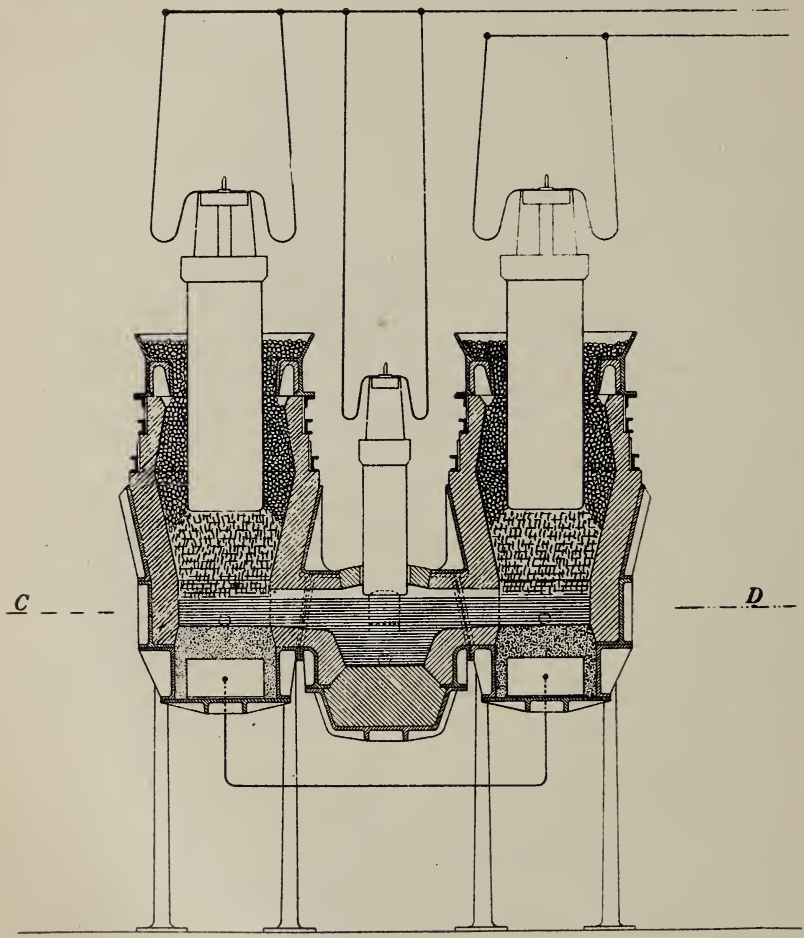


FIG. 2.—KELLER ELECTRIC HIGH FURNACE WITH A PLURALITY OF HEARTHS.

(2) *The Keller Process.*—This furnace is illustrated in Fig. 2, and is the invention of M. Keller of Keller, Leleux and Co., of Livet, France. The charge is introduced between the carbon blocks of the base and ends of the electrodes, which latter are then in their lowest position. The current passes from one electrode through the material to be reduced to the other carbon blocks, from thence outside of the furnace by means of the copper conductor to the other carbon block, and through the charge in the second shaft to the other

electrode. The current meeting in the two shafts with the resistance of the charge, the latter is heated; the reduced metal flowing along the canal conducts the electric current from one electrode internally to the other electrode. The exterior current diminishes as the amount of metal increases. The electrodes are now raised, the charging continued, until finally the electrodes occupy the normal position, and the shafts below the electrodes and the sides of the shaft are completely occupied by the charge. When the Canadian Commission visited the works of Keller, Leleux and Co. some experiments were performed by Keller on the reduction of hematite. The results of these experiments gave an average yield of one ton of pig iron per 0.35 electrical H.P. years; and the pig iron produced could be varied in composition as desired. Mr. Harbord, the metallurgist who accompanied the commissioners, estimates that the cost of iron by Keller's process is about $12.05 per ton.

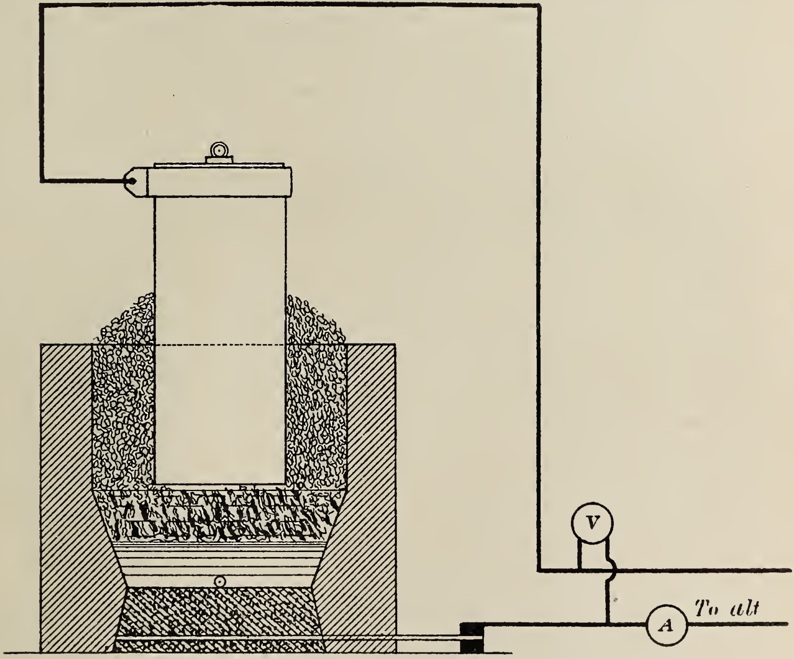


FIG. 3.—DIAGRAM SHOWING ELECTRICAL CONNECTIONS OF THE FURNACE EMPLOYED FOR MAKING PIG IRON AT LA PRAZ.

(3) *The Heroult Process.*—The design of Heroult furnace as used by the Commission in an experiment at LaPraz, France, is shown in Fig. 3. In mode of operation and principle it resembled the Keller process.

Very recently, as is well known, some experiments on iron reduction were made by Dr. Haanel at Sault Ste. Marie. The furnace used was a design of Heroult and is shown in Fig. 4. The object of these experiments was to investigate the following points:

(1) "Can magnetite, which is our chief ore, and which is to some extent a conductor of electricity, be successfully and economically smelted by the electric process?

(2) "Can iron ores with comparatively high sulphur content, but not containing manganese, be made into pig iron of marketable composition?

(3) "The experiments made at Livet with charcoal as a reducing agent in substitution for coke having failed, could the process be so modified that charcoal, which can be cheaply made from mill refuse and other sources of wood supply useless for other purposes, could be substituted for coke? This is especially important since charcoal and peat-coke constitute home products, while coal coke for metallurgical processes required to be imported into the provinces of Ontario and Quebec."

The classes of ore treated were hematite, magnetite, pyrrhotite, and a titaniferous iron ore. As reducing agent was used either charcoal or peat in the form of briquettes. Alternating current of 5,000 amperes and 40 volts was used. The average consumption of power was 0.267 electrical H.P. years per ton of pig iron, and the charcoal used averaged 1,100 lbs. per ton of pig iron. As a blast furnace usually requires 2,000 lbs. of coke, the gain in this is 900 lbs. (assuming, of course, that 1,100 lbs. coke would be required in the electric process), and therefore the electrical power which amounted above to 0.267 electrical H.P. years must cost less than 900 lbs. of coke if the electrical furnace is to compete with the blast furnace.

With coke at $6.00 per ton, this makes the maximum cost of electrical power at $10.00 per H.P. year. In Table 1 I have given a tabulated summary of the experiments mentioned by Dr. Haanel in his preliminary report.

In the column under the head of "slag," I have given the composition of the latter in terms of the ratio between the percentages of silica and of bases present. Thus the basicity of the slag increases from experiment No. 1 to No. 7. In the next column to this I have given the ratios between the percentages of sulphur in the slag and the corresponding values in the metal. It will be noticed that as the basicity of the slag increases so does the sulphur in it; but experiments 5 and 6 form an apparent exception. This is however explained because of the high phosphorus content in the iron in those two cases. These facts are of the same nature as have been observed in the ordinary blast furnace and Bessemer processes. A very basic slag helps to drive out sulphur from the metal, but high phosphorus content retards the elimination of sulphur; and furthermore, it has been claimed that a very high temperature prevents oxidation of the phosphorus and causes the iron to reduce the phosphates in the slag. It is probably due to the very same causes that the phosphorus in the ore was not eliminated in Dr. Haanel's experiments.

Table No I

No	Ore			Iron				Slag	Distribution of S in
	Source	P	S	C	Si	S	P	$\frac{acid}{base}$	$\frac{Slag}{Metal}$
1	Magnetite (Wilbur)	0 01	0 01	4.80	1 55	0 016	0 026	0 56	16
2	Hematite	0 044	0.002	4 55	0.95	0 018		0.55	31
3	Magnetite (Blairton)	0.016	0.06	3.70	3 50	0.042	0 034	0 54	48
4	Magnetite (Calabogie)	0 02	0.17	4.20	1 75	0 05	0 047	0 47	296
5	Magnetite (Calabogie)	0.42	0.45		1.52	0 015	0 51	0.424	88
6	Magnetite (Calabogie)	0.37	0.20	3.47	1.01	0 02	0 50	0 328	78.5
7	Pyrrhotite	0016	1.56	3.0	4.9	0.007	0 05	0 214	800

The experiment on pyrrhotite is very important. A blast furnace will not usually handle high sulphur ores, and requires therefore

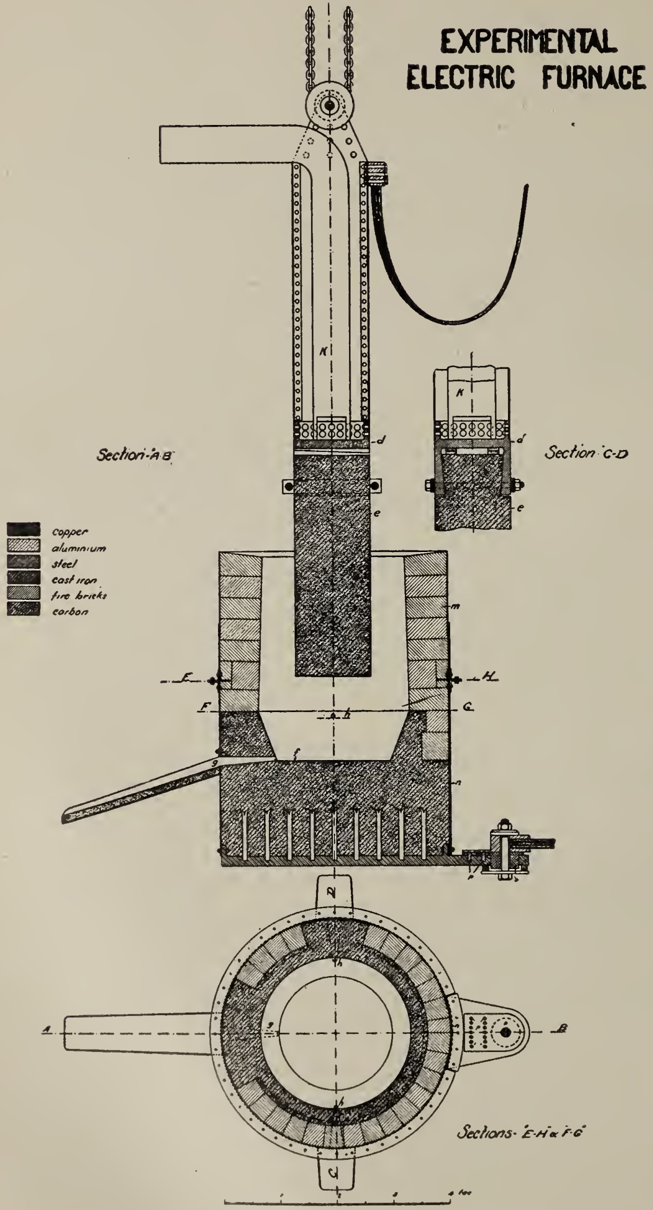


FIG. 4.—ELECTRIC FURNACE EMPLOYED BY DR. HAANEL AT SAULT STE. MARIE.

an ore which cannot be bought in Canada at a low figure. Dr. Haanel has stated that he understands the Algoma Steel Works paid $3.75 for the hematite ore which they use in their furnace. Pig iron equal in value and lower in sulphur contents can be made by the electric process from high sulphur ores which can be bought for $1.25.

The conclusions given by Dr. Haanel at the end of his report are as follows:—

(1) Magnetite can be as economically smelted by the electrothermic process as hematite.

(2) Ores of high sulphur content not containing manganese can be made into pig iron containing only a few thousandths of a per cent. of sulphur.

(3) The silicon content can be varied as required for the class of pig to be produced.

(4) Charcoal which can be cheaply produced from mill refuse or wood which could not otherwise be utilized, can be substituted for coke as a reducing agent without being briquetted with the ore.

(5) A ferro-nickel pig can be produced practically free from sulphur, and of fine quality, from roasted nickeliferous pyrrhotite.

(6) The experiment made with a titaniferous ore containing 17.82 per cent. titanic acid, permits the conclusion that titaniferous ores up to perhaps 5 per cent. titanic acid can be successfully treated by the electric process.

In 1903 Keller delivered a paper before the Iron and Steel Institute on this subject, and made this statement: "It may be stated at once that the employment of electricity as a reducing agent is only practicable from an economic point of view, first when it is a question of manufacturing special qualities of iron from pure ore delivered at the works on favorable terms; secondly, when it is desired to foster an iron and steel industry in a country hitherto undeveloped in this respect, into which all the coal must be imported, where iron ore of good quality abounds, and where natural resources of power are available in the immediate neighborhood of the ore deposits. The scale of production of an electric furnace is less than that of a blast furnace, and on this account the establishments equipped for electric working would be of less capacity and the working expenses proportionately higher. But the iron produced may be made much purer in the electric furnace. A further advantage consists in the higher temperature of working which the use of electricity permits, without, however, causing an excess of carbon in the material. It is also possible in consequence of the hot working to form slags of ultra-basic character."

The prospects of the electrical iron industry in Canada would therefore appear very bright. The provinces of Ontario and Quebec contain both iron ore and plenty of water power; as shown in the above experiment charcoal can be used as a reducing agent. The electrical processes would have therefore very many advantages over blast furnaces. It is to be hoped that our Government will see fit to promote this new industry and thus develop Canadian enterprise in one more direction.

METHODS OF PRODUCING STEEL FROM PIG IRON.

In the ordinary metallurgical processes pig iron is converted into steel by oxidizing the sulphur, phosphorus and silicon as well as some of the carbon. The process used for this varies according to the nature of the pig iron. In the electrical furnaces used for this object the oxidation is performed by adding ore and flux in sufficient quantity to oxidize part of the carbon and slag out the phosphorus and sulphur. The chief processes used are the following:

(1) The Kjellin process.

" At the Gysinge works, steel of superior quality is made by the smelting together of charcoal, pig, and scrap in an electrical furnace of the induction type." Fig. 5 illustrates a 225 H.P. furnace as used by Kjellin. The primary current is 3,000 volts and 50 to 90 amperes. The cost of producing steel by this method is about $1.45 per ton, the cost of power being estimated at $10.00 per H.P. year. The process is adapted for the production of high carbon steels and very little slag is produced. The product compares favorably with the best crucible steel made in Sheffield and the cost is much smaller. In the crucible process about 2½ to 3 tons of coke is used per ton of steel, and even in the large gas-fired furnaces employed in Germany and America probably one ton of slack coal costing not less than $2.50 per ton is necessary.

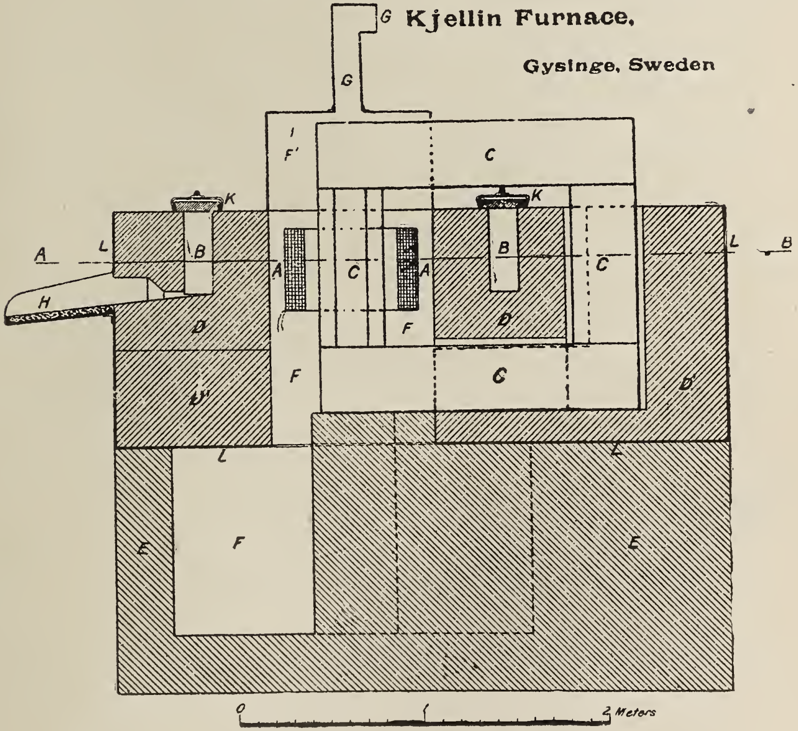


FIG. 5.—KJELLIN FURNACE.

The induction furnace has however many disadvantages due to its electrical construction which will prevent its capacity from being made much larger.

THE HEROULT PROCESS.

The furnace used is shown in Figs. 6 and 7. The current passes from one electrode through the narrow air gap left between the electrodes and the slag line into and through the slag to the molten metal, along it, through the slag and the second air gap to the other electrode. An alternating current of 4,000 amperes at 110 volts is used. The scrap and iron ore, together with the flux used for the charge, are calculated beforehand, and then the slag is removed from time to time until steel of proper composition is obtained. To produce high carbon steel an alloy of iron and carbon called carburite is added to the molten bath. Thus this process has the advantage over that of Kjellin because it permits the puri-

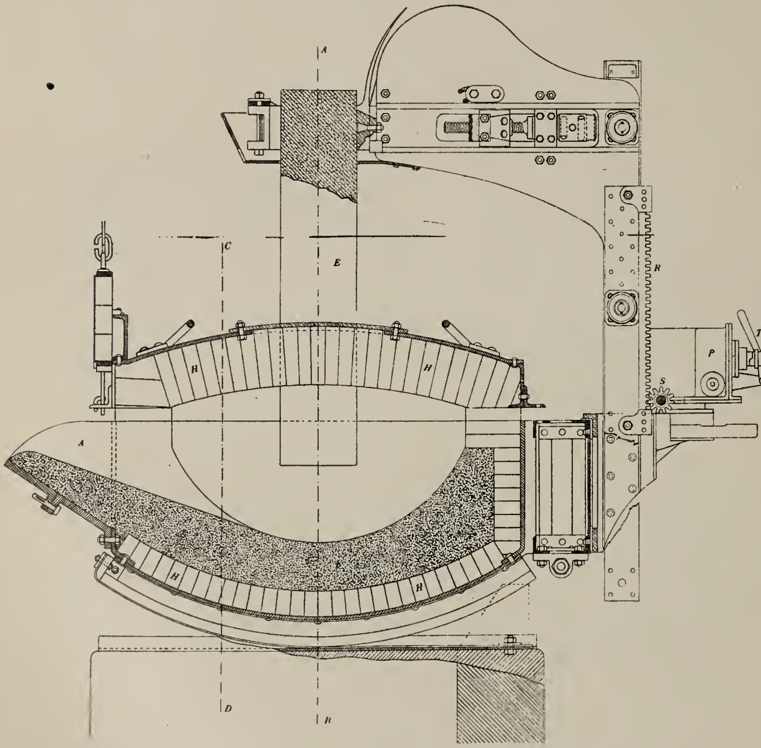


FIG. 6.—HEROULT STEEL FURNACE: TRANSVERSE SECTION.

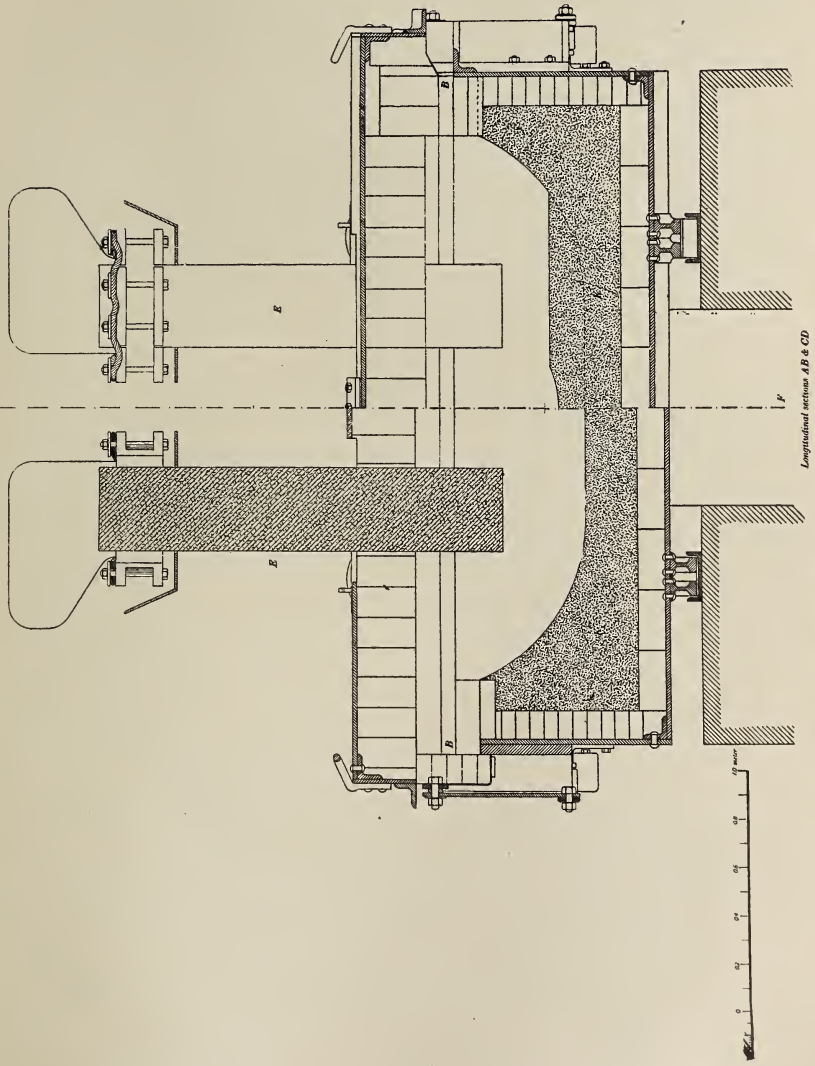


FIG. 7.—HEROULT STEEL FURNACE: LONGITUDINAL SECTION.

fication by renewed slags of the materials originally put into the furnace. The cost of making steel by this method is about $1.70 per ton. A gas fired Siemens furnace producing similar material would require about 1,200 lbs. slack coal at $5.00 per ton, *i.e.*, the cost of fuel would be about $3.00. Thus there is a balance in favor of the electrical method. There is a further advantage that owing to the high temperatures attainable a more basic slag can be used and thus completely remove phosphorus and sulphur. The only disadvantage is that at present the capacity of such a furnace can be increased to possibly 15 tons, but not much higher. It is of interest that on April 4th, 1906, a Heroult steel plant was started at Syracuse and is operating splendidly.

THE KELLER PROCESS.

The principle of this is really the same as that used in the Heroult furnace previously described. An interesting feature is a combination of pig iron and steel furnace which M. Keller would adopt. The latter is a simple crucible with two electrodes suspended in it. The molten pig is tapped directly into this refining furnace, where the phosphorus, sulphur and silicon are slagged out by a suitable flux. The electric power consumed in this method is even less than in the Heroult process. The power used in making one ton of mild steel is about 1-10 of a h.p. year, so that the cost is very small, and with power even as high as $30 per h.p. year, the cost would be smaller than in any metallurgical process. In recent articles published in The Electro-chemical Industry, it has been shown that the waste gases from blast furnaces contain a great deal of available energy for power. This could be utilized in gas engines at a cost of about $30 to $40 per h.p. year. It is therefore very probable that electric furnaces for producing steel will be a common accessory in the future to all blast furnaces. In fact the field for utilizing electric power in the production of steel is much more enticing commercially than the processes of making iron from the ore. It must not be forgotten that the works of Keller, Kjellin and Heroult are producing steel that is competing successfully against the best English crucible and Siemens products.

Electrical smelting is used almost exclusively for the production of the very infusible alloys of ferro-silicon, ferro-chrom, ferro-manganese, etc. These alloys have proven useful for the production of various special steels and the demand for them is increasing. The conclusions that can be drawn from the work done in this field so far seem to be that the electrical furnace is far superior to other existing processes for the production of special high grade steels and refining steel from scrap. There also seems to be a bright future for a large electric mixer to secure uniformity in the product of an entire works, as has been proposed by both Keller and Heroult.

There is still another direction in which the electric furnace may benefit the iron and steel industry. At present the foundry man who makes castings of cast iron usually leaves the steel castings for another firm that makes a specialty of these, but with the electric furnace he need not do this. At a nominal cost for power he could produce castings of steel from the smallest size up to probably 15 ton masses. Every machine shop might have a small electric furnace, in which could be melted the iron or steel to produce its own castings. For the small manufacturer this would prove of great assistance and advantage.

I have attempted in this paper to give the reader a rapid view over the great field in which the electric furnace is being used. If in some ways it is a fad just now, the time is not far distant when it will be a universal appliance, and by its manifold applications will add one more victory to the many already achieved by the indomitable and persevering scientist.

A FEW POINTS ON RAILROAD TERMINALS, WITH SPECIAL REFERENCE TO ROUNDHOUSES.

R. E. W. Hagarty, '07.

On account of the popularity of railroad engineering among School of Science men, I have thought that a few points on Railroad Terminals might be of interest. This article is intended to enlighten, in a general way, those whose experience may have been on a different class of engineering work. The subject is broad; necessarily the remarks will be limited, and will be almost entirely descriptive.

I wish first to deal briefly with the general lay-out of terminal yards, and then to discuss some accompanying structures. Of these, I wish to give special attention to the roundhouse, owing to its somewhat unique design.

In the general plan of yard lay-outs, the factor of prime importance is simplicity. By this is meant that as far as possible, without seriously increasing the cost of obtaining suitable ground, all tracks should be parallel, and have as little curvature as possible. The number of switches on the main line tracks should be minimized. The reasons for the foregoing are as follows:—First, a yard laid out with these ends in view, naturally facilitates the systematic and expeditious shunting and "spotting" of cars; second, and most important, a complicated system of tracks and switches increases the chance of delivering a fast train on to the wrong track and therefore adds to the probability of accident. Large terminal freight yards are divided into sections for receiving and classifying incoming cars and for "making up" outgoing trains. In such yards gravity, or a system of up and down grades, is made use of to assist in shunting, this type being known as a "gravity yard." The grade used in the gravity yard is about .333%; if much heavier, say .5% or more, the wear and tear on both brakes and brakesmen is considerable.

Examples of good terminal yards are those of the Canadian Pacific Railway, recently laid out in the west of Winnipeg; also the Montreal terminals. The Pennsylvania R. R. terminals at Philadelphia have been considered the ideal American model.

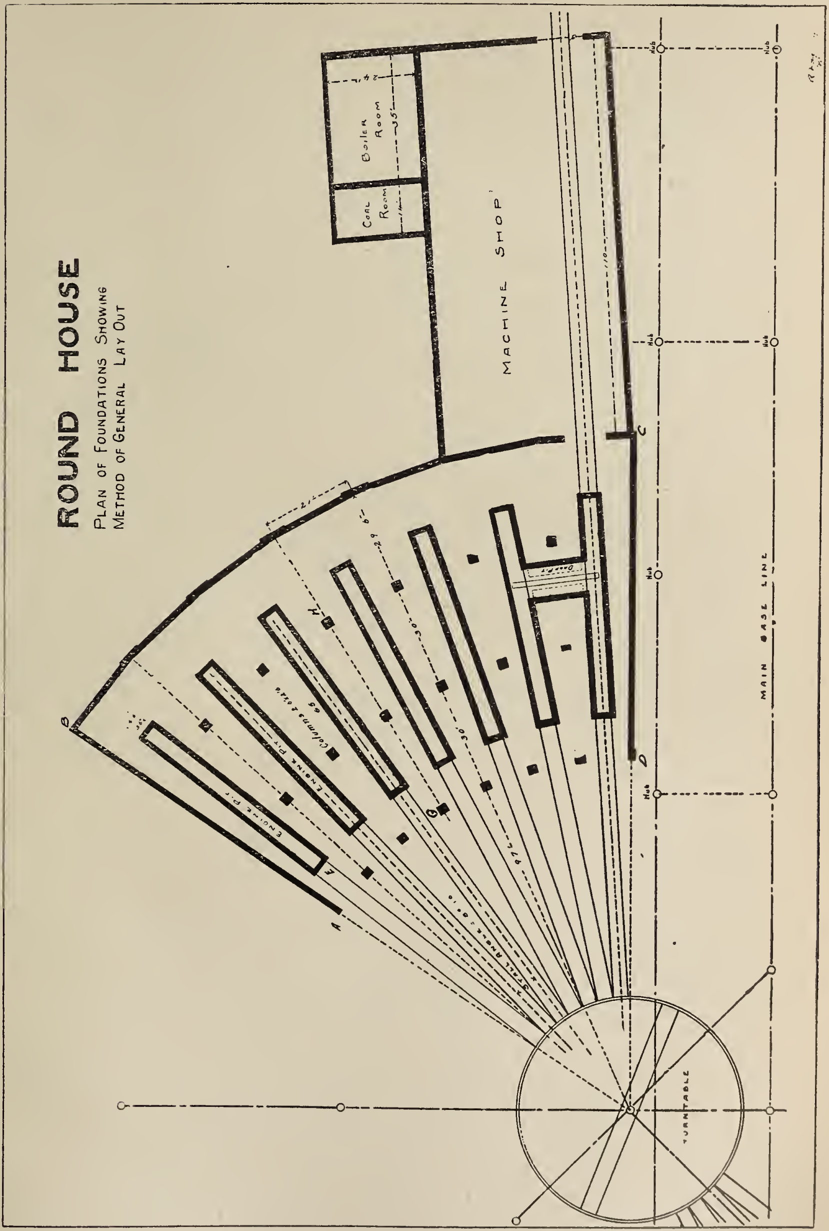
Of the structures in connection with terminal yards, one of the most important is the engine house with its attached repair shops, the two usually built together. They are used for housing locomotives when not in use, for cleaning them and making repairs. The older and somewhat less expensive form of engine house was a rectangular shed, built of timber or corrugated iron. In various ways it resembled the modern street car barn. The tracks were, in some cases, placed in the shed diagonally, thus economizing not only the ground space occupied by the house, but the amount of wall building. However, the objection to this form of engine house was that a large amount of ground was required for track approaches, and in large cities, where land is expensive, the additional cost was considerable. The usual modern type is a polygon-shaped structure built in circular form around a turntable, with tracks leading radially from the turntable into the shed portion. This is commonly known as a "roundhouse." Its chief advantage lies in the fact that only one approach track is needed, this track leading to the turntable. The space used for this purpose is therefore much less than is required in the case of the rectangular shed. But this advantage is to some extent counteracted by certain drawbacks worthy of notice. This turntable system renders it impossible for more than one engine to be taken out at a time; consequently, the roundhouse is a veritable fire trap, and when a number of engines are in the house at once there is the possibility of great loss to the road in the event of fire. Moreover, should the turntable break down, a serious blockade of engines might occur, and the traffic accommodation seriously impaired for several hours or even days. However, by care in the selection of a fireproof building material, and in securing solid turntable foundations, these disadvantages may be minimized. This fact, together with the natural tendency for one road to copy another, may account for the general adoption of the roundhouse. The structure may be built as a full circle, as is usually done on large, well established roads. The number of tracks radiating into the shed will, of course, depend on the size of the turntable and the track width. The larger the circumference of the turntable circle, the greater the number of tracks of a standard gauge which can be accommodated by this perimeter. But on small, new roads, first cost is an important practical consideration, and consequently roundhouses are usually built in the form of a segment of a circle, capable of extension. A typical foundation plan of such a structure is shown in the accompanying diagram.

I shall attempt to outline briefly the process of construction of a roundhouse as shown on the attached plan.

EXPLANATION OF THE DIAGRAM.

A B and C D are the end walls built on radial lines from the centre of the turntable. Their length is determined by that of the longest engine on the road. B C is the outside wall, and consists of a series of panels forming chords of a circle of which the centre of the turntable is the centre. E F is one of the seven or eight "stalls." The stall is simply the portion of the track on which the engine stands when in the roundhouse, and its centre line is also a radial.

G and H, etc., are columns to support roof. A D, the inner circle of the shed portion, is taken up almost entirely with doors, hinged on the columns and the extremities of the end walls. The track of one stall, extended, should lead directly into the machine shop, and, at the point where it enters the shop, there should be no curvature if it can be avoided. In case it is unavoidable, it is preferable to put in a sharp, and consequently a short, curve, as lengthy curves in a roundhouse are a waste of space.


ROUND HOUSE
Plan of Foundations Showing Method of General Lay Out
Boiler Room
Coal Room
24'
35'
Machine Shop
110'
21'
29' 6"
30'
30'
97'
Engine Pit
Engine Pit
Drop Pit
Columns
Stall Angle
A
B
C
D
E
G
H
Hub
Hub
Hub
Hub
Hub
Hub
Hub
Main Base Line
Turntable

Two of the most important considerations an engineer in charge of construction has to deal with are: 1, the selection of the exact location for the building, and, 2, the method of laying out the work on the ground. The roundhouse should be so situated as to admit of being close to the water tank, coal-chutes, etc. In case of building merely a segment to start with, care must be taken that the roundhouse, when extended in completion of the circle, will not interfere with the main-line track or any permanent structure. Railroad terminals are chosen preferably on flat and consequently very often low and unsolid ground. Hence foundations are an important consideration in choosing the exact site. In other words, the engineer's task in this connection is usually one of making the best of a bad bargain.

In regard to foundations, there are several points to be kept in mind. If the ground is low, a thorough system of off-take ditches should be first constructed. In case of muskeg, it will be necessary to drive piles. If rock is obtainable at an average depth of a few feet below the surface, it is advisable to build directly on the rock. However, uniformity of subsoil is most desirable, as uneven settling causes serious cracks to appear in the walls after construction. The entire clearance of rock is advisable unless rock can be obtained under the whole foundation.

The site selected, the details of lay-out next come in for consideration. Obviously the centre of the turntable is the first point to be selected, because from it points in almost any part of the lay-out may be determined by a system of angles and linear measurements. The first thing to be done by the engineer is to plant a substantial transit hub. This being established, the direction of one of the end walls, say C D, may be selected and used as a base line. By chaining a calculated distance (97′ in a specific case I have in mind), the inner extremity of this end wall may be located. Similarly the other extremity. Then by turning off a calculated angle (say 8° 16′) the direction of the centre line of the first stall is established, and any required points on this line may be found by chaining. Similarly the other stalls, points on the outside wall and the position of the columns may be accurately located. Owing to the vital importance of the centre of the turntable, it is necessary to reference it thoroughly by a system of base-lines, so that it may be accurately replaced at any time during construction.

CONSTRUCTION OF ROUNDHOUSES.

In constructing roundhouses, the fire-proof qualities of the material should be kept in view. Formerly brick or stone or a combination of these was used; but latterly, on account of its cheapness and its absolutely fire-proof properties, reinforced concrete has been largely, almost exclusively, adopted. The walls of the structure consist of a six or eight-inch footing course three feet wide, imbedded a few feet below the surface of the ground and surmounted by an eighteen-inch wall up to the elevation of the base of rail, and above this a twelve-inch wall to the roof. The footing course is reinforced by strips of band-iron imbedded horizontally in the concrete near the bottom, to resist the tension produced by the lateral bending moment in the three-foot course. The columns supporting the roof are reinforced by four half-inch iron rods imbedded vertically in the columns, which are spanned at the tops by reinforced beams. The concrete used in these walls, columns, etc., is by certain specifications a mixture of five parts of gravel, three of sand, and one of Portland cement. Sometimes broken stone is used instead of gravel, in which case the fragments by specification should pass through a two-inch ring. The concrete, whether mixed mechanically or otherwise, should receive thorough and constant inspection, as a slight deficiency in the proportion of cement used might cause a serious failure.

I shall now briefly describe the other features of the roundhouse, such as engine-pits, drop-pits, roof, doors, lighting, ventilation and turntable. The engine-pits are shallow pits between the rails of the stalls, the width being governed by the track-gauge. They are used for making light repairs to locomotives, and also for washing. The wash water, and, in winter, the melted ice and snow from the engine, drips into the pits and is thence carried off by drains. A drop-pit is placed at right angles to one of the engine pits and is used for removing axles or other heavy portions of the machinery.

The roof of an engine-house may be covered with slate or tarred felt, but of late the use of asbestos roof-boards has come into vogue. Other materials are corroded by the sulphurous gases from the engine smoke. The roof may be supported in two ways: first, by a roof-truss; second, by columns. The roof-truss method involves a considerable amount of extra space to be heated in winter. By the use of columns it is possible to obtain a comparatively flat roof, and therefore less space to be heated. The columns, while serving this purpose, in no way interfere with the operation of the roundhouse. Hence this form of roof support is economically preferable.

The doors, which are practically always swung, are sometimes designed with rounded tops. The justification of this design is entirely aesthetical, but the plain, square-topped doors are less expensive, and more in keeping with the unpretentious environments that necessarily prevail.

The interior should be well lighted. Hence the window space should be as large as possible, lights being inserted in the outside wall, and, as transoms, over the doors. For night lighting, electricity should be used, if possible, to decrease the danger of fire.

For ventilation, each stall is provided with a smoke jack. This is merely a pipe with a bell-shaped mouth so placed as to cover the locomotive smoke-stack and carry off the smoke through the roof.

One of the most interesting parts of the roundhouse system is the turntable. This is usually a steel plate girder, revolving on a pivot which, during revolution, carries the whole weight of locomotive and girder. The importance of the pivot foundation is obvious, and it is desirable, if at all possible, that these foundations should be placed on rock, a feature which in case only a small amount of rock is available, should be taken into account under the head of location at the outset. The diameter of the turntable is of course governed by the longest engine on the road. When properly balanced, the turntable, with the engine, is usually revolved by hand, one man being able to push the whole weight. In some cases a small electric motor is used. As the engine is leaving the turntable, the poise is of course disturbed, and the end of the girder drops a couple of inches, where it is temporarily supported by a circular rail.

WATER TANK AND COAL CHUTES.

Other terminal structures related to the roundhouse in importance and situation are the water tank and the coaling station, the latter being technically known as "coal chutes." The details for these have become standardized, so there remains for the engineer in charge of construction only the fulfilment of those special conditions peculiar to any specific case.

The source of water supply, of course, first decides the location of the water tank. This should be conveniently near the roundhouse, coal chutes, ash pits, etc. If the ground is soft, piling may be necessary; the required number of piles may be estimated by computing the weight of the structure obtained from the "bill of material" by a reference to a Carnegie or similar handbook, adding the weight of water and allowing about four tons of the total weight to be carried by each pile. The piles should be arranged symmetrically under each post of the structure supporting the tank. They should be driven till the final drop of a two-ton hammer falling through 20 feet buries the pile not more than an inch or two. The piles may be capped by timber or by concrete piers, the head of the pile projecting into the concrete about one foot. The substructure supporting the tank is of timber or of light structural steel.

It is important to notice that where winter is severe precautions must be taken to prevent freezing. The simplest and most effective method of accomplishing this result is to "jacket" the tank or to surround it by a wall of two thicknesses of Manitoba siding, separated by a six-inch air space, which is found to have considerable frost-proof qualities. In addition, steam pipes are usually placed inside the tank. An average railway water tank has a capacity of about 50,000 imperial gallons.

A simple form of coal chute is an elevated shed some 30 feet wide, and of length to suit the required capacity of several hundred tons. Along the side of this shed a through track is laid, close enough to admit of coal being fed to locomotives by means of apron doors. This track should be open at both ends, that is, connected at each end with a main-line or main-line feeder track, so that more than one locomotive may take coal simultaneously. The coal chute is approached by a trestle with a grade inclination not exceeding four per cent. A long period of development in railway engineering has caused the designs and the methods of practice to become largely stereotyped. However, in the preceding remarks I have endeavored to enumerate such points as in themselves may seem to be important; still, experience has shown that lack of foresight in regard to such points as these might easily cause, and has caused, serious defects in the laying out and the construction of railroad terminals.

MANUFACTURE AND PROPERTIES OF WROUGHT PIPE.

F. N. Speller, B.A.Sc.

Prior to 1886 all welded tubes and pipe were made of wrought iron. In that year a small quantity of pipe was successfully made of soft steel, at the Riverside Works of the National Tube Company, Wheeling, W.Va., but the successful development of soft welding steel has really been accomplished only during the past ten years. The manufacture of this grade of steel is now a special branch of the steel industry, furnishing a material having many advantages for mechanical welding.

At the present time about 25% of the welded tubes and pipe are made of wrought iron. The proportion has been growing constantly less since the introduction of steel. Two principal grades of iron are now being made:—(1) charcoal iron for boiler tubes and (2) common wrought iron made by the well known puddling process.

The manufacture of charcoal iron is one of the oldest and most interesting metallurgical processes. The first step in refining is accomplished in the refinery or run out fire, as it is called. Charcoal pig iron contains about 95% of metallic iron, the remaining 5% being carbon, silicon, manganese, phosphorus and sulphur. In the " refinery " the silicon and manganese are practically eliminated with about 50% of the phosphorus. This furnace consists of a rectangular hearth with water cooled sides, over which is a hood and stack. The hearth is 15 inches deep below the tuyere line. Rotary blowers supply blast at a pressure of 2 lbs. per square inch, which impinges on the molten iron in the hearth through inclined tuyeres on each side; the silicon and manganese and some of the iron oxidize forming a slag which combines with suitable cinders added with the charge and acts as a carrier for the removal of a certain amount of the phosphorus and sulphur. The refined metal is run out into a chill mold, broken up when cold, and piled awaiting the next operation, which is conducted in the "Knobbling Fire." This is a slightly modified form of the old Catalan Forge, which in the dawn of the iron-making era was used to produce wrought iron direct from the ore. The refinery metal is reheated by waste heat from a previous charge in lots of 400 lbs., and in turn is drawn down into the forge and heated by side blast in a bed of charcoal. The arrangement is very primitive and has not seen much improvement since the days when the grandfathers of the present knobblers worked their forges in Sweden or Wales.

The metal melts and drop by drop trickles down through the charcoal, losing its carbon under the highly oxidizing environment, and forming a strongly oxidizing and basic cinder which removes a considerable part of the remaining sulphur and phosphorus contents. Additions of cinder from previous heats help the reduction and economize iron. At the finish the knobbler has a pasty lump of crystals of iron roughly welded together and intermixed with cinder. The last operation consists in hammering this lump so as to remove the cinder as completely as possible. After the first hammering, the bloom is reheated and again placed under the steam hammer, from whence it is taken to the break down mill, where it is rolled to a bar one inch thick. These bars are cut up and piled four high, reheated, and rolled in a continuous mill to a plate of the required gauge and width with scarfed edges. This puts the iron in shape for the tube and pipe departments. The process of refining at each stage of the operation can be best illustrated by average analyses of the material given below:—

	Total Carbon %	Mang. %	Silicon %	Phos. %	Sulp. %	Oxides & Cinder %
Pig Iron......	3.85	.98	.94	.086	.025	———
Refinery Mtl...	3.50 (comb)	Trace	.21	.070	.024	———
Finished Plate.	Trace	Trace	.014	.024	.014	.92

The second and coarser grade of wrought iron required for the manufacture of pipe is made by the puddling process, which need not be touched on here. Practically no improvement has been made in this process since the introduction of cheap steel. The grade of iron thus made for welded pipe contains on the average:

Silicon	.100%
Phosphorus	.220%
Sulphur	.020%
Manganese	Trace
Carbon	Trace
Oxides and slag	2%

The manual labor connected with the making of all grades of wrought iron is severe and the skill required quite considerable. Owing to the inducements in other fields to-day it is difficult to recruit the dwindling ranks of old time operators with younger men, since with the intelligence required to make a good knobbler or puddler, a man can now-a-days make more money at other work and lead a less strenuous life. These processes have served their purpose well and will doubtless hold their own for a while for special purposes, but the natural course of evolution seems to point to the passing of such methods, especially as modern practice improves the quality of steel, which now competes with iron in all lines. Wrought iron is hard to regulate in quality, principally on account of (1) irregularities in composition of pig iron used; (2) the small quantity made in one heat; (3) the personal attention and skill required on the part of the puddler, and the large personal equation thereby introduced. The iron of to-day is rendered still more unreliable by the practice of some makers who intermix steel scrap of uncertain composition, thereby, of course, lessening the cost of manufacture.

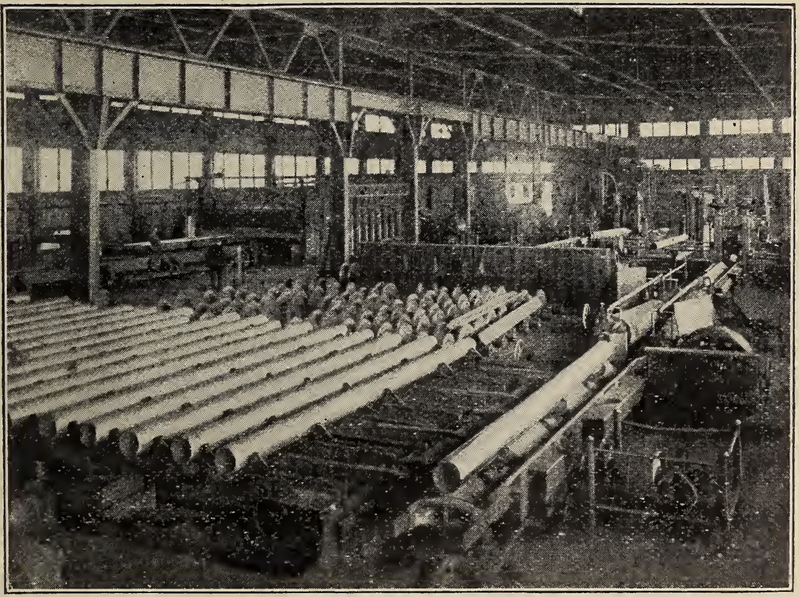
By carrying the Bessemer process to the limit of refining, and treating the metal so as to give the best results in welding, a refined iron is produced practically uniform in quality. which will roll into a plate with a true edge—a very desirable condition for good results in the pipe mills. To obtain the best results it is necessary to manufacture "pipe steel" on a scale sufficiently large to take the full capacity of a steel plant. Under these conditions it is probably safe to say that uniformity of product is obtained unequalled in any other class of steel manufactured on this scale.

A smaller proportion of pipe and steel is made by the Basic Open Hearth process, but the easy control and continuous supply of uniformly very low carbon steel which can be had from a Bessemer plant running in conjunction with pipe and tube mills, and the satisfactory nature of the product, have caused the Bessemer process to become firmly established for this class of work. The higher phosphorus and sulphur contents of Bessemer steel are no objection in welding pipe where the quantity of metal used is so greatly in excess of what strength requires, and moreover these elements become a necessity if the pipe is to be tolerably easy to thread. Pipe steel welds with greater ease and with much less loss on account of blisters and laminations than wrought iron.

MODERN LAP WELD MILL FOR LARGER PIPE—CHARGING END.

GROWTH OF TUBE AND PIPE INDUSTRY.

The production of welded tubes and pipe has almost doubled in tonnage since 1899. During this period the process of making pipe steel and mechanical welding by the butt and lap weld process has been much improved, giving a more uniform product and at the same time reducing costs all round. The introduction of pipe steel has apparently had somewhat the same influence in expanding the field of use for tubular goods as the advent of structural steel exercised on the production of materials of construction, formerly made of wrought iron. In 1905 the production of tubular goods in the United States (1,435,995 tons) nearly equalled that of rolled structural shapes (1,660,519 tons) not including plate. The production for 1906 promises to reach 1,700,000 tons.



FINISHING SIDE OF WELDING FURNACE—COOLING TABLES IN FOREGROUND.

The generally good welding quality of wrought iron enabled it to maintain its position as the metal for the manufacture of pipe years after it had been displaced by steel as a material for general engineering construction. In 1890 about 3% of the welded pipe was made of steel; in 1905 this had increased to 70% and it is estimated that steel pipe will constitute 80% of the output for 1906. Besides the general use of pipe in steam, water, gas and oil lines, which consumes the larger part of the tonnage, increased amounts are being used for trolley poles, electric conduits, bedstead construction and for other special purposes.

Among the special uses to which steel pipe lends itself, the catenary system of trolley suspension might be referred to. Large quantities of the small sizes of extra strong pipe are used in making the light triangular frames from which the live wire is suspended in high speed electric railroad construction. The joints are either threaded, or flattened and pinned together. Steel pipe combines a maximum strength for its weight, very desirable for such work. Wherever pipe has to be bent or worked either hot or cold the modern material has a decided advantage.

In the California field a quantity of steel pipe has been rifled, the object being to cause the viscous oil intermixed with a small per cent. of water to whirl as it moves rapidly through the pipe. When a sufficient velocity is attained, a layer of water flows between the oil and the pipe, reducing the friction in the line.

It has been found quite practicable to roll spiral corrugations 3-32-in. deep in the surface of the pipe by means of six wheels set equidistant around the circumference and slightly inclined to the axis of the pipe, so as to make a complete revolution on the surface of the pipe every 10 feet. The material appears to stand this treatment cold without difficulty.

It might be well to refer here to the heat treatment necessary to anneal pipe steel. The heat required to weld iron or steel produces a larger grain in the metal. For most purposes this does no harm and steel pipe unannealed will stand remarkably severe cold bending without fracture, having an elongation of 20 to 24% in 8 ins. in this state, but where the pipe has to be worked hot it is advantageous to first heat it to a full orange (above the critical range of 900 degrees C.) for a few minutes and then allow the metal to cool slowly in the air. This will completely remove all possible effect of overheating, by refining the grain, and will enable the metal to be worked without danger from red shortness. Tubes or pipe will stand more cold working if so annealed. The ends of boiler tubes should be given this treatment before being expanded and rolled into the flue sheet.

PRINCIPAL PHYSICAL CHARACTERISTICS OF PIPE MATERIALS.

From the manufacturing standpoint, the superior welding quality, uniformity and lower cost of pipe steel are the determining qualities. The tensile strength of pipe steel pulled transversely is about double that of wrought iron, hence the welded seam might be expected to be proportionately strong. This has been shown to be true by experiments on 2-in. butt welded pipe. The average strength of the weld was thus found to be 70 to 72% of the strength of the metal transversely in each case, and the steel weld proved to be twice as strong as the wrought iron. Bursting tests on wrought iron and steel butt welded pipe confirm these conclusions. The strength of the seam was compared by twisting pieces about 8 feet long until they failed. The following results were obtained on three sizes of standard pipe:

TABLE I.

TWISTING TESTS ON BUTT-WELDED PIPE.

SUMMARY.

Size.	Material.	Make.	Wt. Per Ft.—lbs.	Variation from Card Wt. %	MAX. PULL ON 3 FOOT LEVER—LBS.			Number of Turns in 6 Feet	% Failed in Weld.
					Low.	High.	Average.		
$\frac{1}{2}$ in.	Steel	N. T. Co.	.816	—2.2	90	120	109	15	0
"	Iron		.803	—4.2	40	98	$68\frac{1}{2}$	$4\frac{1}{2}$	73
"	Iron		.792	—5.2	20	113	81	$5\frac{3}{4}$	66
"	Iron		.842	+0.6	50	85	65	$2\frac{1}{2}$	100
$\frac{3}{4}$ in.	Steel	N. T. Co.	1.082	—2.9	160	185	172	8	13
"	Iron		1.097	—1.6	140	160	154	$6\frac{1}{5}$	33
"	Iron		1.127	+1.0	80	176	136	$3\frac{1}{2}$	66
"	Iron		1.104	—1.0	50	160	107	$2\frac{1}{2}$	90
1 in.	Steel	N. T. Co.	1.658	—0.7	180	340	300	$5\frac{1}{2}$	13
"	Iron		1.593	—4.4	220	292	256	$4\frac{1}{2}$	46
"	Iron		1.616	—3.1	170	300	250	$3\frac{1}{3}$	33
"	Iron		1.620	—2.8	100	320	258	$3\frac{3}{4}$	66

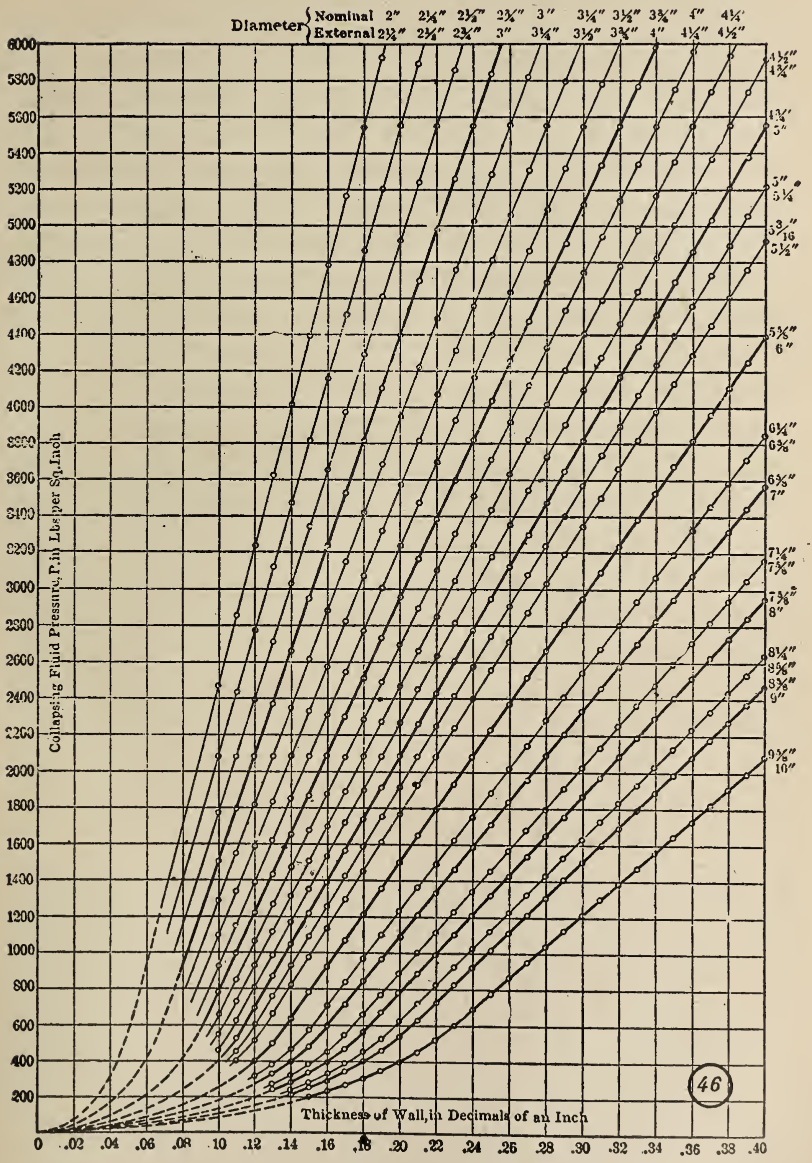


Diagram of collapsing pressures

Pipe steel finishes with a smoother surface than wrought iron, which for some purposes is very desirable.

A list of the physical properties of steel pipe would not be complete without referring to the exhaustive series of tests made on the National Tube Company's lap weld steel pipe by Prof. R. T. Stewart, to determine the collapsing pressures. This work employed from one to six men for four years and involved the collapsing of nearly four hundred pieces of pipe, 3 ins. to 10 ins. in diameter, mostly 20 feet in length. The details may be had by reference to Prof. Stewart's papers in Trans. of Am. Soc. of M. E. for this year.

THREADING PIPE.

Steel pipe has been objected to by some, chiefly on account of the fact that it is somewhat harder to thread with the poor dies with which many threading shops are equipped, and which are too commonly sold to the trade. It is to be expected that a practically pure iron will offer more resistance to a blunt and improperly shaped die, than will a metal like puddled iron, in which are intermixed layers and strings of cinder amounting to 2 or 3%. The power required to thread with a die, is approximately proportional to the tenacity of the metal. By properly grinding the chasers and providing relief so that the heel does not drag, the difference in power required to thread iron and steel disappears and much better results are obtained with less wear and tear on the dies.

Considerable unnecessary trouble has been caused through die makers not recognizing the importance of these points, especially to the small operator depending on hand power. It may seem to some a rather elementary point to emphasize before this Society, but we even now occasionally hear from large well-equipped shops up-to-date with nearly all modern improvements, yet ten or fifteen years behind in their die equipment. It is not surprising that many should have preferred wrought iron where much threading and cutting has to be done, as it is only within the past year or two that the much needed improvement has been introduced by certain makers of standard hand dies.

CORROSION OF IRON AND STEEL.

This is a question which has brought forth many opinions, but in most cases with little practical evidence. After investigating closely many cases which have come under my observation during the past two years, where the two materials were put in service together and subject to the same conditions, I have never yet found any decided difference. The impression which exists in some minds that wrought iron pipe is much superior to steel in durability, may have originated in comparisons on pipe made years ago when the practice of making sound low carbon steel was probably not so well understood as it is to-day, or it may have been a mistaken identity, for we frequently find iron mistaken for steel, especially if it happens for some cause to be pitted, but in most cases the idea has apparently been spread by hearsay and accepted without investigation.

In view of the inherent differences between iron and steel made for various uses, it would seem safer to compare each class by itself, i.e., wire, sheet, pipe, etc., each under the conditions of service to which it is subject.

The essential conditions of corrosion, air, water and carbonic acid, are easily duplicated in the laboratory, but in practice corrosion is accelerated by presence of sulphurous and other solutions, stray electric currents, heat anl numerous other influences difficult to trace.

It will be conceded that such conditions tending to seriously affect corrosion, are rapidly on the increase, especially in and near the great centres of population. Hence we should be slow to draw conclusions from the statement that steel does not last now-a-days as it did 15 or 20 years ago. Whatever the relative standing of the two materials was years ago (and opinions differ widely), what we are more concerned with is, how do they stand to-day, and how can they be best protected from corrosion? Laboratory results, while open to criticism, as not truly representing actual conditions in the field, are valuable as indicating the relative standing of a number of samples under conditions known to be uniform—some-

Average Results of Recent Comparative Tests on Corrosion of Wrought Iron and Pipe Steel.

(*Losses* per unit of surface exposed compared with Puddled Iron as 100)

No. 1	Conditions of Test.	Authority.	Duration of Test.	Charcoal Iron.	Puddled Iron.	Pipe Steel	Test Standard
No. 2	Aerated distilled water. Normal Temp.	U. S Navy Dept.	64 Weeks	100		94.5	1901
No. 3	Sea water Normal Temp.	H. M. Howe	2 Years		100	119	1897
No. 4	Aerated Brine	Lab'ry. Nat'l Tube	6 Months		100	106	1904
No. 5	Aerated water 180 deg. F.	"	3 Months		100	90.6	1905
No. 6	Aerated brine 180 deg. F.	"	3 Months	80	100	75.3	1906
No. 7	Aerated sea water 180 deg. F.	F. Howe	3 Months	94.4	100	94.2	1906

thing difficult to be sure of in service tests. The writer has in his tests lately used a 5% hot solution of brine through which a continuous flow of air is pumped. One reason for adopting this solution is that a number of tests are on record which indicate that steel in general seems to be somewhat more susceptible to this environment than wrought iron, and further that the loss is quite considerable in a reasonable time (about 1-10 gram. per sq. in. per month). Some averages of a number of results on pipe material are given herewith, comparison being made with good wrought iron as a standard.

There are two possible ways of protecting steel: 1st, by use of efficient protective coatings; 2nd, by treatment of the metal in the course of manufacture. Experiments have been carried on by the writer for some time at the works of the National Tube Company, with the object of increasing the durability of pipe steel. As a first step in this direction a process has been developed which after a year and a half's trial has given results showing a decided benefit to the steel, especially in the uniformity with which it corrodes. The treatment consists in a mechanical working or kneading of the metal which tends to produce greater uniformity and improve the quality and texture of the steel. Doubtless much of the steel does not need this treatment, but in such cases it does no harm, and on the whole raises the average standard of the output. Tests marked Nos. 5, 6 and 7 were made on this steel.

It has been recognized that service tests must be made before any certain conclusion can be reached. A number of such tests have been made on this steel pipe in sulphurous air, salt water and mine water during the past year, precautions being taken to have an equal number of pieces of "genuine" wrought iron pipe alongside under the same conditions. The results so far have shown the steel so treated without exception to be at least the equal and generally decidedly superior to wrought iron.

The latter portion of this paper, dealing with the characteristics of pipe material and its corrosion, was read before the Engineering Society of Western Pennsylvania, in November, 1906.

CONTINUOUS BEAMS.

A. W. Connor, B.A., C.E.

Problems in continuous beams are much more frequently met with in the design of structures of reinforced concrete than of steel. For concrete beams are, from the nature of their construction, rendered continuous over their supports. With the rapid growth of concrete construction, the study of the action of the continuous beam is in consequence of much more general interest now than formerly, when it was very generally limited to the case of swing or cantilever bridges. It is not proposed however in this brief paper to discuss the general theory, but to give a few applications of it to problems on which the author was unable to find any reference in the standard works. It is believed that these results might be of interest to your society.

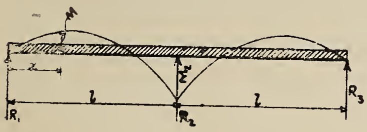
No doubt the lack of published information and the difficulty of solving the general equations has led to rule of thumb methods of designing continuous beams, or to the entire neglect of the effect of the continuity. The continuous beam is more economical than the discontinuous beam, and the failure to treat it as continuous has not only been wasteful in material, but has marred many buildings by the excessive deflection and cracking of the floors. As far as the reputation of the designer is concerned, such a floor is as fatal as an actual collapse of the same. The subject is then of sufficient importance to merit a careful study of the conditions of stress in all parts of the beam.

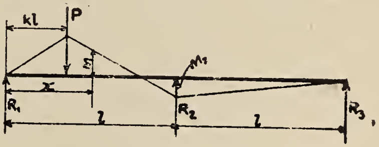
The fundamental theory, by means of which any problem in continuous beams may be solved, was first published by Clapeyron in 1857, and with subsequent additions by Weyrauch and Merriman, is known as the "Equation of Three Moments." It is based on the elastic theory and on the assumption of a uniform moment of inertia throughout the length of the beam. It is also assumed that the beam is freely supported, not fixed, and that the supports are on a level, or to be more exact, that in its unstrained condition it rests freely on all its supports.

There is an erroneous impression in some quarters that the continuity of action in concrete beams in a building depends on the rigidity of the columns. Such rigidity tends to give the condition of a beam fixed at the ends. In practice no doubt the actual condition of the beam is between a continuous beam freely supported and one fixed at the supports. In other words the inclination of the beam at the supports lies between that given for continuity and the horizontal position given by fixing the ends. It will be instructive to compare the moments and shears of a beam continuous over several supports and one fixed at the ends.

Below will be found some results for beams continuous over two or three equal spans of length l. From the equations given it is an easy matter to determine all the other conditions of stress.

TWO EQUAL SPANS.





1. Uniformly distributed load p per foot. The maximum positive moment at any point in either span occurs when that span only is loaded. This loading will also cause the maximum negative moments in the far end of the other span.

The moment curve is a parabola on the loaded span, and a right line on the other span

$$\text{Max. Mom.} = .0957\, pl^2 \text{ when } x = \frac{7}{16}\, l$$

$$M_2 = -\frac{1}{16}\, pl^2$$

If both spans were loaded $M_2 = -\frac{1}{8} pl^2$ which gives the maximum negative moment. Since the loading is symmetrical, the beam is horizontal at the centre, and is then in the same condition as a beam fixed at one end and supported at the other, and the moment at the fixed support has the same value.

The negative reaction, $R_3 = -\frac{1}{16} pl$ due to the left span only being loaded will be neutralized by continuing the loading .426 l past the centre support.

2. Concentrated load P at distance kl

$$R_1 = \frac{P}{4} (4 - 5 k + k^3).$$

The maximum positive moment will be under the load.

$$M = \frac{P}{4} (4 k - 5 k^2 + k^4) l$$

This will have a maximum value, $M = .2074 \; Pl$ when $k = .433$.

The maximum negative moment will be at the centre pier, $M_2 = -\frac{P}{4} (k - k^3) l$, and will have a maximum value of $M_2 = -.0962 \; Pl$ when $k = .577$.

3. Two symmetrical loads of P at distance kl from each end.

$$R_1 = \frac{P}{2} (2 - 3 k + k^3)$$

The max. pos. moment is under the load,

$$M = \frac{P}{2} (2 k - 3 k^2 + k^4) l.$$

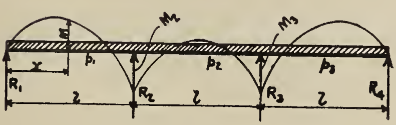
It will have a maximum value, $M = .174 \; Pl$ when $k = .366$.

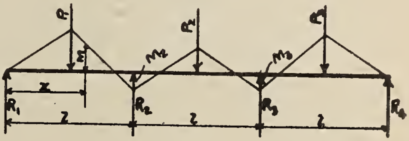
The max. neg. mom. will be at the centre pier, $M_2 = -\frac{P}{2}\left(k - k^3\right)l$ and will have a max. value, $M_2 = -.1925 \; Pl$ when $k = .577$.

As the moment is always negative at the centre pier for any loading, it was to be expected that this latter value would be twice that given for a single concentrated load as in case 2. It will also be noted that, as the loads are symmetrical, the values given above are the same as for a beam fixed at one end and supported at the other. When the load is at the centre of the spans (or at the centre of a beam fixed at one end and supported at the other) then $M = \frac{5}{32} Pl$. Some books give this as $\frac{3}{16} Pl$, which is clearly erroneous. The negative moment at the fixed end is however $= -\frac{3}{16} Pl$.

THREE EQUAL SPANS.

l = length of each span.
M_2 and M_3 = bending moments at intermediate supports.





4. Uniform loads p_1, p_2 and p_3, per foot on spans 1, 2 and 3 respectively.

$$M_2 = -\frac{1}{60} l^2 (4\ p_1 + 3\ p_2 - p_3)$$

$$M_3 = -\frac{1}{60} l^2 (-\ p_1 + 3\ p_2 + 4\ p_3)$$

If the loading is uniform throughout $M_2 = M_3 = -\frac{1}{10}\ pl^2$. The other moments and reactions are easily determined from these equations.

5. Concentrated loads P_1, P_2 and P_3 at the centre of spans 1, 2 and 3 respectively.

$$M_2 = -\frac{1}{40} l\ (4\ P_1 + 3\ P_2 - P_3)$$

$$M_3 = -\frac{1}{40} l\ (-\ P_1 + 3\ P_2 + 4\ P_3)$$

If the loads are all equal, $M_2 = M_3 = -\frac{3}{20} Pl$. These moments are thus seen to be 50% greater than if the same load in each panel were uniformly distributed.

6. Two concentrated loads each of P_1 P_2 and P_3 placed at the third points of spans 1, 2 and 3 respectively.

$$M_2 = -\frac{2}{45}\, l\, (4\, P_1 + 3\, P_2 - P_3)$$

$$M_3 = -\frac{2}{45}\, l\, (-P_1 + 3\, P_2 + 4\, P_3)$$

These moments are thus seen to be one-third greater than if the same loads in each span were uniformly distributed.

The above are some of the problems more frequently met with in practice. The subject might be considerably extended if desired. Nothing has been given on the question of the deflections in continuous beams, an important subject that might well merit further consideration.

OBITUARY NOTICES.

GEORGE ALEXANDER BREBNER.

George Alexander Brebner, whose death occurred at Schenectady, on February 21st, this year, was born in Sarnia, on January 1st, 1875. In 1891, after the completion of his high school training, which was taken in his native town, he entered the Faculty of Arts in the Provincial University and completed successfully the first year in the following spring. In October, 1902, he registered as a student at the School of Practical Science, and was graduated in the spring of 1905. While a student, his vacations were spent with the Blaikie Foundry Co., Sarnia, the Peterson Machinery Company, Sarnia, and the McKee and Marwick Company, Petrolea, with whom he remained two years after graduation. In August, 1907, he entered the Students' course of the General Electrical Company at Schenectady, N.Y. In this work he showed marked ability, and during the Spanish-American war was specially employed on the testing of search lights for the War Department of the Federal Government. Afterwards he was transferred to the switchboard department, and for a number of years was chief estimator, and practically head of that branch of this Company's operations. In October, 1906, he was promoted to the power and mining division, where the estimating of the cost of power equipments, many of them of large magnitude, was his special work. Shortly before his death, he had completed an estimate on the cost of a gigantic electrical installation for what will shortly be one of the manufacturing centres of the Illinois Steel Corporation. Similar undertakings had recently occupied his attention in Minneapolis and St. Paul.

Brebner had shown conspicuous aptitude for electrical engineering, a profession in which his abilities and industry had already secured him very responsible positions. His fatal illness, which lasted only a week, was the result of an accident.

JOSEPH P. BELLISLE.

Early last May the students of the School of Practical Science were shocked to hear of the death of Joseph P. Bellisle, one of the most promising graduates of the class '06. He had been engaged as one of a survey party in New Ontario and left shortly after examinations to begin the summer's work. The party had gone up the Montreal river and were almost at the scene of their labors when the canoe capsized in a rapids, and the deceased, although a strong swimmer, could not endure the icy waters, and was drowned.

Mr. Bellisle was born at Georgetown, and received his early education there. He taught school a year and a half and then entered the employ of the Toronto Street Railway. He entered the School in the fall of 1903 and took a course in Mining Engineering, graduating in 1906. He was called away before he knew of his success at the final examinations.

The deceased was one of the best known men of his year. His indomitable pluck and perseverance made his undertakings successful, and no doubt had he been spared he would have made a name for himself. His genial disposition, good fellowship and generosity endeared him to all his acquaintances.

J. CAMERON PAULIN.

J. Cameron Paulin was born at Arthur, Ont., March 7th, 1886, and was the youngest son of William Paulin, a retired farmer of that vicinity.

His preparatory education was received at Arthur High School, and after completing his senior leaving, he entered, in the fall of 1905, the Faculty of Applied Science in the department of Mining Engineering.

The vacation of 1906 was spent as Mr. T. B. Speight's assistant on base line and meridian work, in New Ontario, and after a successful summer he returned strong and hardy for his second year at the School.

Possessing a fine physique and robust health, he was an enthusiastic devotee of outdoor athletics, and in the fall sports had always been a vigorous participant.

On the afternoon of October 3rd, during Rugby practice, he received a fatal injury in the skull, which resulted in a cerebral hemorrhage. He was carried to the Kappa Alpha chapter house, where medical attendance was summoned. In the evening it was perceived that complications had set in and he was removed to the hospital, where he expired a few moments after his arrival. The body was taken home to Arthur for interment.

Cameron Paulin possessed extraordinary courage and ability, and the breadth of his maturing character won for him the respect and love of all who knew him.

FRED. CODE.

The late Mr. Fred. Code, whose death through typhoid fever occurred at Smith's Falls, on October 29th, 1906, was the son of the late Wm. Code, of North Elmsley, and was at the time of his death just thirty years of age.

Having completed his high school course at Smith's Falls in 1894, he taught school at Roseville for a number of years, resigning in 1901, to enter the Civil Engineering Course in the School of Practical Science. He graduated in 1904, and returned in the autumn of the same year to take the post-graduate work in Astronomy, which he completed with honors the following spring. He was shortly afterwards appointed town engineer of Smith's Falls, which position he filled in a capable and faithful manner until the time of his fatal illness.

Needless to say, the taking away of one who in early manhood gave promise of such a brilliant and useful future, has occasioned general regret among a wide circle of friends. Of a studious and retiring nature, exemplary habits and possessing an upright and honorable character, he won the respect not only of intimate friends but of all with whom his business brought him in touch. He is survived by a widowed mother, four sisters and four brothers, one of whom, Mr. S. B. Code, was a class mate of the deceased.

W. J. BOWERS.

The unexpected death of Mr. W. J. Bowers in December, '06, came as a shock to a large circle of friends and acquaintances. Of unusually robust constitution, Mr. Bowers would have been considered particularly capable of resisting the dreaded fever which he had contracted, but the adversary proved the stronger and death came after a few short weeks of illness.

Mr. Bowers was one of the out-going class of 1901, and prior to his student days had been employed for three years with the Bell Telephone Company in Toronto. After completing his work at the School of Science, he spent three years with Mr. Willis Chipman, Civil and Sanitary Engineer. From 1904 until the time of his death, he was employed with Mr. John Galt on Municipal Engineering, chiefly, his position being that of chief assistant of the eastern work. In the Engineers' Club, of Toronto, Bowers had always taken an active interest, and had for some time previous to his death filled with every satisfaction the position of Treasurer. This work brought him in contact with the members of the profession in the Toronto district, and his geniality and good fellowship were proverbial with an extended and constantly extending circle. He is survived by a widow and three children, who have the sympathy of the community in their bereavement.

TREASURER'S REPORT.

Toronto, March 26th, 1907.

Mr. President:—

I beg leave to submit the following report for the year ending March 27th, 1907:—

To balance on hand	$ 485 56
“ amount of life members' fees	42 00
“ amount of annual fees	2 00
“ library proceeds	1,410 00
“ receipts from advertising	225 25
“ receipts from sale of pamphlet	50
“ Government grant	75 00
“ balance from dinner	44
“ amount from old account	66 44
	$2,307 19

By amount of publishing pamphlet No. 19	$ 406 47
“ “ expenses incurred by old executive	41 36
“ “ printing account	74 28
“ “ paper and supplies	1,058 30
“ “ commission, discount and postage	82 98
“ “ pin	2 25
“ “ customs and freight	10 51
“ “ representatives' expenses	76 00
“ “ editor's salary	50 00
“ “ librarian's salary	50 00
“ “ photos, etc.	18 40

By amount	present to Mr. Loudon	$ 25 00
" "	typewriting	11 55
" "	flowers and funeral expenses	28 35
" "	refund on life membership	1 00
" "	election expenses	57 25
" "	Students' Parliament	15 00
" "	Engineering meeting expenses	20 00
" "	balance in bank	278 49
		$2,307 19

RESOURCES.

Amount due from Mr. Laing, fees	$ 468 75
Other outstanding debts	146 08
Supplies on hand	451 03
Cash on hand	278 49
Total	$1,344 35

G. E. QUANCE,
Treasurer.

AUDITORS' REPORT.

We have this day examined the books of the Treasurer of the Engineering Society and find them correct.

H. V. MAYNARD, } Auditors.
J. McGOWAN, }

Toronto, March 26th, 1907.

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Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 21 NOVEMBER, 1907 New Series Vol. 1, No. 1

PRESIDENT T. H. HOGG'S SPEECH AT INITIAL MEETING OF ENGINEERING SOCIETY

GENTLEMEN,—I am glad to see such a representative gathering of the Engineering Society present with us this afternoon, for this opening meeting will be a memorable one for many reasons. We meet as a representative body of the undergraduates and staff of the Faculty of Applied Science, for the first time an integral part of the University and we have with us to-day President Falconer, the herald of the new regime. It is fitting therefore that we should meet in Convocation Hall where it is hoped many more of our meetings will be held.

To the gentlemen of the first year, who are with us for the first time, we extend a hearty welcome. In the past few days you have had an opportunity of viewing things and becoming familiar with a slight portion of the work that will be yours during the coming session. But in this work let me impress on you the desirability of your hearty support of this society, desirable not only to the society from the advantages flowing from that support, but desirable also from the benefits accruing to yourself. In the schools you have just left you have been subjected to a certain amount of restraint and now you find that restraint removed. In the first moments of freedom you may feel that your presence or help here is not required, but we should remember that it is only with the combined work of all that the work of the Society can be a success.

To the gentlemen of the higher years, allow me to again thank you for the honor you have placed on me in electing me to this position. In placing the officers of the Society in their respective positions, you lay on them a duty which it is hoped they will fill to your satisfaction. But by putting the executive work in the hands of certain men you do not thereby relieve yourselves of your responsibility to the Society and to the Faculty. It is your duty, and, I am sure, will be your pleasure, to aid by your regular attendance at meetings and by the furnishing of papers of interest to the undergraduate body.

With the increased number of meetings due to the recent change in the constitution it is hoped that papers from students will be oftener forthcoming, as the discussions of these papers are productive of much good to the individual men and to the Society. It is impossible for the executive committee to find all the men who might deliver addresses on interesting topics and we ask your hearty co-operation in this. We should remember that the same law follows here as in all other things, that we get only so much out of the Society as we put in, and that only inasmuch as we devote time and energy to the work of helping others. in that ratio, do we obtain any material benefit from our work.

We have with us to-day, to address us, President Falconer, who will represent to us the academic and educational side of our work, a side which, it is hoped, will broaden and grow under his wise guidance. We have Doctor Ellis, the Acting-Dean of the Faculty of Applied Science, who, in the absence of Dean Galbraith, will deal more particularly with the technical aspects as placed before us in this Faculty, and, while we regret the unavoidable absence of the Dean, whose work on the Royal Commission aupointed to inquire into the Quebec bridge disaster, reflects such credit on the whole University, still we feel that in Doctor Ellis, a worthy substitute appears.

To complete the programme, Mr. C. H. Mitchell, the representative of our graduates on the University Senate, has kindly consented to give the professional side, and we feel that with his broad experience in engineering, and by his close contact with the undergraduate body, he is well qualified to give us some useful glimpses of the profession and the outside world, thus blending the professional, technical and educative phases of our work.

I have much pleasure in calling on President Falconer to address us.

PRESIDENT FALCONER'S ADDRESS TO ENGINEERING SOCIETY

Mr. President, Members of the Executive and Gentlemen,—It is a great pleasure for me to come this afternoon and to be present at the opening meeting of the Society. It seems to me that this Society is in many ways a very unique Association, because its vitality appears to have been maintained so steadily and to have played a very active part in the furtherance of your interests. Mr. Hogg, I am sure, is right when he says that its success will depend to a very great extent on the amount of energy you put into it. In my college days we found that the amount of result in any Association depended on the amount of labor expended upon it. I hope this will be a very prosperous session for you, and since I have been speaking nearly every day for the last two

Robt. A. Falconer

weeks, I promise you that I shall not detain you long at this time.

The chief fact which I wish to emphasize is that you belong to a very great profession. The engineering profession is one of the newest, and the Faculty of Applied Science is also one of the most recent in this University, although probably its state should be considered rather more as one of transition.

Engineers have during the last dozen years been forcing their way to the front, so that to-day you occupy a place among the leading professions of the world. This is an indication of the way the world is changing, and it involves on your part a recognition of certain facts you may sometimes forget. A profession involves a great deal. A professional man is not one who enters upon a certain calling in life merely to make a living; he is more than that. When any occupation rises to the dignity of a profession it at once enters upon a new stage. Of course it is needless to say that no professional man is indifferent to the emoluments of his profession, and it is legitimate that he should expect to make a good living out of his profession, but there is more in a profession than making a living. In coming into a profession you join a fellowship of men who besides making a livelihood are furthering the interests of human life by advancing knowledge in different branches. The growth of the scientific and the change in our views of life have been such that to-day your profession has been given a status and a dignity which was not accorded it in the past. (Applause).

What then consitutes a profession? First, technical knowledge. When you go out into your life you must know what to do on being brought face to face with certain problems. Therefore in the Faculty of Applied Science you are taught the details of this necessary technical knowledge which must be drilled into you by a process of hard study and hard work. (Applause.) But I shall not linger on this phase of the subject since it is obvious that whether you are a mining engineer, a mechanical engineer, a civil engineer or an architect, or whatever it may be, this technical knowledge is requisite to further your advancement.

The next thing that I regard as essential is that you should have a disciplined and well-trained mind. Not only must you know how to solve the ordinary difficult problems which you will meet in your profession when you go out in the world, but you should have a thoroughly well-disciplined mind in order that when you are brought face to face with a new difficulty you may know how to study it and to master it. You will encounter problems you never had any idea of, before you went out, and your ability to handle these problems depends on the way in which you are master of your own intelligence. A professional man is supposed to have his faculties under such control that he is able to apply them correctly to the circumstance in which he may find himself.

Another thing which an engineer should have is a certain amount of breadth. I want to emphasize this because there is a tendency to think that in a University Course there is a vast amount of unnecessary dwelling on abstract ideas, and not on what you may consider to be the practical side of life. In the new world many are falling into the great mistake of so preparing themselves as though they were to make a living only for the next ten years. It is not only ten years that you are concerned with; it is a lifetime that may last twenty-five or thirty years or longer, and you must remember that at the end of thirty years you may be compelled to compete with younger men. You must train yourself now or you will be outstripped in the course. This training to be effective must have breadth. You will go from this University not for a few years but to live a life covering many years. Remember that this University has to lead this country in a great many ways. (Applause.) It depends in part upon you and you must have such provision as to be able to see not just what is at your feet, but you must have a broad outlook and be able to take control of large issues. A strenuous training is needed to give you that control, and there should be such a training in the Faculty of Applid Science that there will be a high average level, and also that every year a certain number of men may emerge above the surface who will make a name for this University and for our country. (Applause.) I know that there is the ability in this University to show to the world what we in Canada can do, and I believe that you have the ability to lead your profession and to be an honor to it. (Applause).

I have something else to say in connection with breadth. I want you to remember that since you belong to a profession and have breadth you must needs seek a certain amount of intellectual culture. You may not think that this amounts to much, but, gentlemen, it amounts to a great deal. You must have certain interests broader than your profession, and the real difference between the man who is narrowed down to his own profession and a man who takes an interest in the various social requirements of his community is soon very evident.

On the way over from the Old Country this last spring I read a newspaper article in which I was very much struck by the phrase "There is a humanity also in engineering." (Laughter). I thought that this was a very suggestive phrase. What did the writer mean? As far as I could see, he meant that in the engineering profession there is a great background of human interest. Ask yourselves what you are doing for the broader life of humanity. You are not only benefiting the country by sinking deep shafts, building railroads and bridges, but if you will only realize it you are appealing to the imagination of the country. A vast work in engineering is as much an appeal to the imagination as some great creation in literature. I can remember standing on one of the piers of the great Forth bridge and watching the interlacing of the structure. The beauty of it touched my imagination and I have since again admired the genius that must have been expended in the construction. Think of the power that is spent in the spanning of a great continent.

Have also some outside interests and be not absolutely absorbed in your work. You cannot be experts in English literature. You have not the time for this as those who make it a profession have. We cannot sit, as it were, in the great garden of literature picking the very best flowers here and there, but we can at times look over the wall and see the beauty or we may glance at the little flower pots at the front of some man's house. Let us take some time for enriching our thought. Get some outside interest that you may not be absolutely absorbed in what you are doing. You say, "I have not time." You have time if you want to make it.

I have already spoken for twenty minutes and I promised I would not detain you long, but there is a third thing about which I wish to speak to you. It is the need for an ethical code in your profession. Besides the three professional necessities, technical knowledge, a disciplined mind and breadth, every profession has or should have its ethical code. In medicine that ethical code has kept up the standard of the profession. Some outside men think that this ethical code in the medical is altogether too stringent, but it has done a great deal and I believe that you must have a high ethical code in engineering and a mutual fellowship that the world may trust you. That is a great thing in a profession. As Engineers you often have the life of the community in your hands. Probably more than the men of any other profession. The medical men also are responsible for the life of the community, but not to such an extent as are the members of the engineering profession. (Applause.) The life of every traveller is in your hands, and it is impossible for any one but an expert to know whether your work has been done well or not. We must rely on the honor of your profession and you must set a high moral standard that the world may trust you. This University will, I believe, turn out men who can be relied upon by the community.

Again, do not allow your professional knowledge to be used by unscrupulous men for the furtherance of their own particular schemes, which may be for the ill advantage of the public. You will sometimes be faced with this temptation. If you go in the direction of money and forget your profession you will be, or you should be, ruled out of it.

I am new to this University as some of you are, but I was glad to hear your President, Mr. Hogg, read the statement about the Students' Parliament, as I think I see the need of such a parliament, and I hope that we may all co-operate in welding the University together, so that there will be no antagonism between faculties but that you may view things in the larger light of the good of the University; that you will be loyal not only to your faculty but also to your University.

It has given me a great deal of pleasure to speak to you this afternoon.

THE EFFICIENCY OF BEAM CONNECTIONS

By C. R. YOUNG

Lecturer in Applied Mechanics

Some years ago a discussion took place between the officials of a well-known bridge company and a firm of consulting engineers as to the use of Carnegie standard beam connections in a building, the steel work of which was being fabricated and erected by the company, according to the general designs of the engineers. The latter had required the above-named standard connections in their specification, but the company objected to them on the score of their lack of efficiency, with the result that the company's own standards were approved and adopted by the engineers.

A comparison of two typical cases selected from the two sets of standard connections will exhibit the basis of the company's contention.

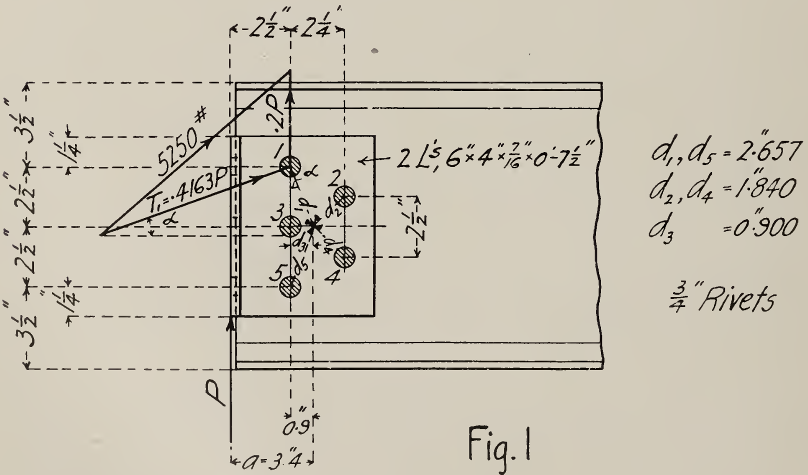

Fig. 1

Consider the Carnegie standard connection for a 12-inch I-beam @ 31½ lbs., as shown in Fig. 1. Assume the maximum allowable end reaction to be P pounds. This force will be applied in the plane of the backs of the outstanding legs of the connection angles. Its effect on the rivets will not be altered if we introduce two equal and opposite vertical forces acting along a line a distance a from the backs of the angles, so chosen that if it were considered to be the line of action of P, the reaction of the rivets against P would be equal, neglecting the effect of the elasticity of the material or errors of workmanship. Evidently this line must pass through the centre of gravity of the rivet areas 1, 2, 3, 4 and 5. Each rivet must then resist a vertical force equal to P divided by the number of rivets in the connection, together with the force brought to bear upon it by the moment of the couple Pa and directly proportional to its distance from the point about which the connection angles tend to rotate. Professor W. H. Boughton, by making use of the principle of least work has shown this point to be the centre of gravity of the rivet areas.*

Finding the position of the centre of gravity, which in this case is seen by inspection to be 2-5 of the distance from the line of rivets 1, 3 and 5 to the line of rivets 2 and 4, we determine the value of *a* and of the distances of the various rivets from the centre of gravity as given in Fig. 1. The distance *a* being 3.4 inches, the moment of the couple is 3.4 P inch-pounds. If the force acting on rivet 1 due to turning effect be denoted by T_1 then the force acting on any rivet at a distance of 1 inch from the centre of gravity due to the same effect would be $T_1 \div 2.657$, rivet 1 being 2.657 inches from the centre of gravity. Similarly the turning force acting on a rivet at a distance *d* from the centre of gravity would be $T_1\, d \div 2.657$ and its moment of resistance would be $T_1\, d^2 \div 2.657$. The moment of resistance of all the rivets is therefore $T_1 \Sigma d^2 \div 2{,}567$. Summing the squares of the distances of all the rivets from the centre of gravity we get 21.7, and since the moment of resistance of the rivets must equal the bending moment on the connection the equation $21.7\, T_1 \div 2.657 = 3.4\, P$ may be written. From this, T_1 the force

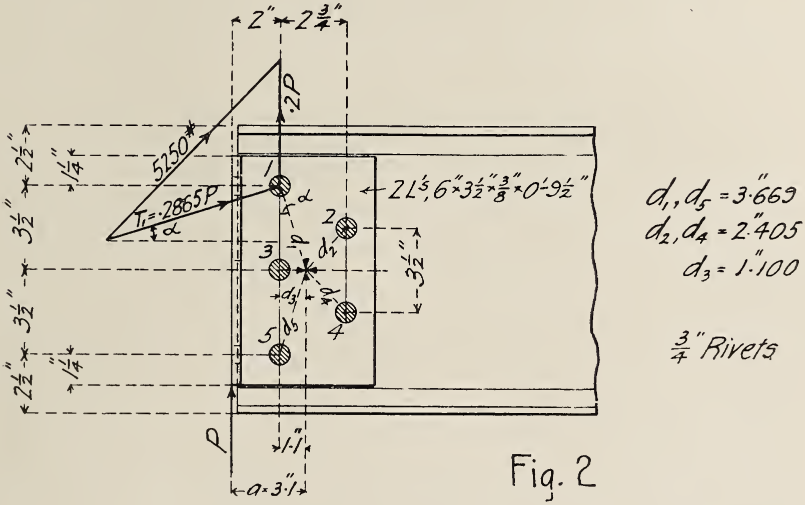

Fig. 2

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* Proceedings of the Ohio Society of Surveyors and Civil Enginers, 1902, p. 24.

acting at right angles to the line d_1 joining rivet 1 with the centre of gravity, is found to be .4163 P. The other force acting on rivet 1 is a vertical one and equal to .2 P. These two forces when combined must not stress the rivet beyond its safe working capacity.

Assuming the allowable shearing and bearing stresses on rivets at 10,000 and 20,000 pounds per square inch respectively, and using ¾-inch rivets, the least safe resistance of a rivet will be determined by its bearing value on the web of the beam which is $.75 \times .35 \times 20{,}000 = 5250$ pounds. The two forces acting on rivet 1 must combine so as to give a resultant of 5250 pounds, for it may be shown that the resultant force acting on any rivet nearer the centre of gravity than rivets 1 or 5 is less than on either of these two.* If, therefore, rivets 1 and 5 are working up to their full capacity, 5250 pounds, the connection is carrying its greatest safe load. Denoting the angle between a vertical line through the centre of rivet 1 and the radial line d_1 as α (see Fig. 1), we may write the following relation:

$$\sqrt{(.4163\ \mathrm{P}\cos\alpha)^2 + (.4163\ \mathrm{P}\sin\alpha + .2\mathrm{P})^2} = 5250$$

from which P is found to be 10,100 pounds.

Let us now investigate in a similar way the strength of the connection shown in Fig. 2 which represents the standard connection for a 12-inch I-beam @ 31½ lbs. used by the contracting company.

In this case a becomes 3.1 inches and the moment of the couple 3.1 P inch-pounds. The turning force on a rivet d inches from the centre of gravity is $\mathrm{T}_1\, d \div 3.669$ and the moment of resistance of all the rivets is $39.7\ \mathrm{T}_1 \div 3{,}669$, Σd^2 being equal to 39.7. Equating the moment of resistance of the rivets to the bending moment as before, T_1 is found to be equal to .2865 P. As in the first case, the resultant force acting on rivet 1 must be 5250 pounds, and we may write

$$\sqrt{(.2865\ \mathrm{P}\cos\alpha)^2 + (.2865\ \mathrm{P}\sin\alpha + .2\mathrm{P})^2} = 5250$$

from which P = 13,300 pounds.

Comparing these two cases, we find that the second form of connection is capable of withstanding a loading 31.7 per cent. greater than the first, while at the same time there is no increase in the number of rivets used and an increase in weight of material used of only 3.6 per cent. Somewhat similar results might be shown on comparing other connections of these two sets of standards.

The conclusion must be that the rivets are not effectively placed in the Carnegie standard connections. They are concentrated too near their centre of gravity where they have little resistance to bending moment, and the line on which rivets 1, 3 and 5 are driven is farther away from the backs of the angles than it need be, thus throwing the centre of gravity of the rivets too far away from the line of the reaction and therefore increasing the moment on the connection. A study of the two figures will show that in the second case great care has been taken to place the rivets where they are most effective for resisting moment and where they reduce the moment to a minimum.

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*See Ketchum's Design of Steel Mill Buildings, p. 153.

STRUCTURAL STEEL VERSUS REINFORCED CONCRETE

R. E. W. HAGARTY, '07

Considering that this is one of the first addresses given before the University of Toronto Engineering Society, under the new arrangement whereby simultaneous meetings are held by the various "Sections" of the engineering practice, I beg to remind you of one of the important reasons for the inauguration of this system; it is as you know to establish and encourage free and exhaustive discussion of engineering subjects in the meetings of these distinct branches of Applied Science, such as the Civil and Architectural Section, to which I have the honor of speaking. In this feature I believe there is a decided advantage. Engineering research may form, in the main, an engineer's life work; consequently we may assume, possibly, that most of us are students or comparative beginners in the complete understanding of our profession, considering this I may perhaps presume to address you. For a highly scientific discourse we naturally look to the man of long professional standing and experience. To most of us, however, the liberal discussion of plain engineering conditions has undoubtedly the decided advantage that the mistakes and difficulties of a student are more apt to be appreciated and explained perhaps, by one who is himself a comparative beginner.

In view of the above I shall endeavor to enumerate the salient points concerning a subject which I have chosen to call "Structural Steel versus Reinforced Concrete." My aim is merely to compare impartially the relative merits of these two systems of engineering construction.

Just here permit me to say, that owing to the limited nature of this address, no more than a mere outline is advisable. Possibly on this account certain lectures given before the Society have been characterized by vagueness. There may be a slight justification for a misconception of this kind, but as I have said, lectures cannot properly be other than a synopsis. So much for by way of introduction.

When an engineering commodity passes the experimental stage and is placed on the market of commercialism, there are several large considerations and severe tests with which it must battle. Theoretical success is fundamental and especially has this been true in the past few years, when engineering practice has been based on the principles of mechanics, physics, and mathematics. Following this comes a demand for practical possibility; many designs like some engineers, are theoretically perfect, but practically impossible; that is such designs are incapable of erection. However, mere compatibility is a primary condition and the next requirement embodies practical success in a marked degree. Reinforced concrete, for instance, is just at this stage. Men of great persuasive ability throughout the country are trying to vindicate, by actual use, the practical success of this commodity. The foregoing are some of the considerations referred to. They are in the main, severe but necessary and beneficial tests. However, there is another test of greater severity than any, one which beginners are apt to neglect, namely that of financial success.

In the case of the proposed 700-foot span reinforced concrete arch in New York, the money problem will hardly be considered. But the extreme rareness of an exception to the universal demand for monetary profit proves the unsurpassable importance of the financial test. While this is imperative, there is, however, a very regrettable feature which induces a tendency to skimp design. You are not unmindful of startling examples of this which have been all too frequent.

The general systems of development of structural materials are similar and especially in the case of structural steel and reinforced concrete. While enumerating the points of advantage and disadvantage of these respective materials, I would like you to note the bearing of each point on the commercial use and misuse of these commodities. I shall consider first structural steel, then proceed to discuss the development of reinforced concrete and finally its adaptation to certain specific examples.

STRUCTURAL STEEL.

Structural steel was originally necessitated by the introduction of railroads about 1839 and its use has steadily increased since that time. It was first used in small culvert spans as beams; and later was applied to the construction of larger bridges. The continuous advancement in the use of steel as an engineering material has been primarily due to certain physical properties considerably superior to those of any marketable substance to-day.

Of these the first is *unit strength* which is exceedingly high in both tension and compression. Merriman gives the ultimate or maximum strength of structural steel as 60,000 pounds per square inch in both tension and compression. The working stress varies from 12,000 to 22,000. The New York Building code specifies the following: "All structural steel shall have an ultimate tensile strength of from 54,000 to 64,000 pounds per square inch. Its elastic limit shall not be less than 32,000 pounds per square inch and a minimum elongation of not less than 20 per cent. in eight inches. Rivet steel shall have ultimate strength of from 50,000 to 58,000 pounds per square inch."

To show a comparison with other materials I beg to quote Merriman as follows: The values are ultimate compressive strength in pounds per square inch.

Brick	3,000
Stone	6,000
Timber	8,000
Structural Steel	60,000

I might also add that an approximate average for concrete is 3,000. Hence, so far as abstract strength is concerned structural steel is eminent; also, considerable uniformity and reliability of strength can be obtained in steel. So strength is an important point for steel.

(2.) In conjunction with the above comes a property almost equally as great, namely *specific gravity* which is for steel about 7.85 and is remarkably low considering the high strength value.

The above are two of the most influential reasons for the adoption and continued use of steel. They indicate theoretical and practical possibility.

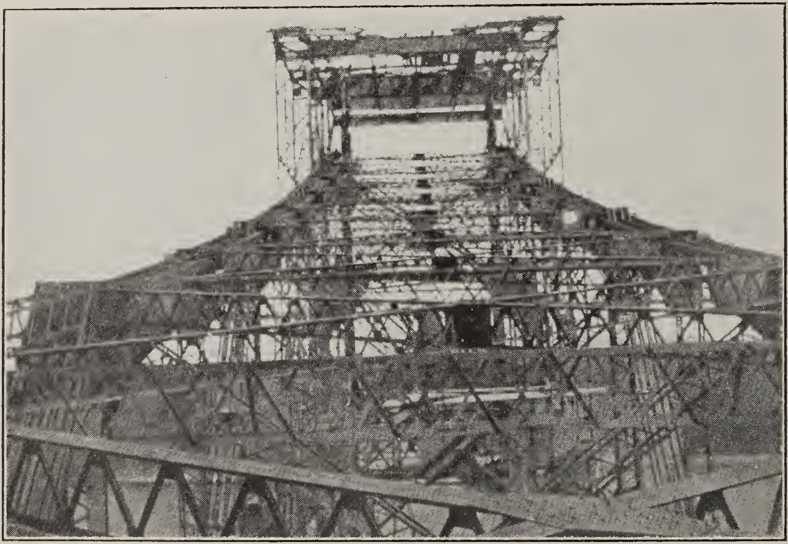
(3.) Another property of considerable importance is *malleability* in mild or structural steel. A specimen of mild steel should in cold bending double on itself without rupture. This condition renders practicable rolling the material into standard shapes such as I's, channels, angles, etc., which are so conveniently and extensively used in structural steel methods of construction.

(4.) A fourth proptrty of steel which also adds to its feasibility is the low and almost constant coefficient of expansion. The rate of expansion per degree Fahrenheit, according to Kent, is from .00000648 to .00000686. Consequently accurate calculations with regard to heat expansion are possible. However, it may be well to point out just here that the rate of expansion for concrete is almost the same.

(5.) The rigidity of steel as indicated by its modulus of elasticity—29,000,000 pounds per square inch is high and comparatively constant up to the elastic limit, while the modulus for concrete is only about 2,000,000 and is not actually constant, making necessary the use of assumptions which to a greater or less extent impair the reliability of theoretical reinforced concrete design.

A consideration of the foregoing physical properties of steel accounts for the theoretical and practical possibility incident with the introduction and continued use of the material. However, its practical success has been due to a series of considerations evinced by practice itself.

(1.) Of these though one of greatest importance seems to me to have been the capacity for *magnitude* of structures designed in what has been at least attempted in steel work kindly permit a few dimensional facts concerning the Quebec bridge. The structure was of cantilever type consisting of deck truss approach spans each 550 feet long; two cantilever arms each 562½ feet long, and one suspended span 675 feet long, the longest simple truss span ever built. The total central clear span of the bridge from pier to pier was to be 1,800 feet, the longest in the world, while the total length of the bridge was to be 3,220 feet. The depth of the truses varied from 97 feet at the portals to 315 feet over the main piers, and the height of the peaks of the main post above the river was 400 feet. The clear headway over high tide was 150 feet and it proposed that the new bridge have a clear span of 200 feet in order to permit vessels of Mauritania type to reach Montreal. Magnitude then is an important capability possessed by structural steel, which may never be approached by reinforced concrete.



South Anchor Arm, Quebec Bridge

(2.) In close connection with magnitude comes the possibility for accurate, delicate and complicated design and construction certainly not attained in any other building commodity yet invented. Even the popular mind is impressed with the marvelous intricacy of many steel structures assembled as they are from members consisting of a few standard rolled shapes, and symmetrically riveted into a fabrication of surprising accuracy and neatness of outline.

The view as shown in Fig. 1 over the top of the south anchor arm of the Quebec bridge illustrates well this point.

(3.) Inspection is a potent factor in the safety of structures. Thoroughness in this respect is facilitated to a high degree in the methods employed in steel construction. A large portion of the work is done in the shop of the bridge company who may be the contractors for a certain piece of steel work. Large members are fabricated in the shop and shipped as unit pieces to the place of erection. Individual members weighing as much as 100 tons were used on the Quebec bridge. It may be easily understood, then, that shop inspection is considerably superior to field inspection which predominates in reinforced concrete construction. Hence the inspection of structural steel is decidedly more reliable than is that of the other system.

South Main Pier, Quebec Bridge

(4.) The same condition that increases the efficiency of steel inspection also increases the probability of first-class *workmanship*. Judging even superficially from the nature of shop work its superiority over field work is evident. The systematic concentration of the designing office, the drawing office, the template shop and the various accessories of the structural work shop such as electric cranes, pneumatic hoists, high pressure punching and riveting machines is bound to induce good workmanship as opposed to the rough-and-ready temporary methods prevailing in the field. This apparency is verified by experience. Years of observation of the manufacture of steel has also had its effect on good workmanship.

The prominence of this argument in favor of steel is also well shown by the Quebec bridge disaster. A professional man viewing the tangled mass of steel which overhangs the south main pier, cannot but observe the excellent character of the workmanship which must have been placed in the material for that bridge. The steel overlying that pier, as shown in Fig. 2, has fallen with a tremendous momentum a distance nearly twice as great as the Traders' Bank Building, Toronto, (nearly 400 feet) and still there appears but little rupture of material or dismemberment of parts.

This is indeed a wonderful tribute to a condition of almost perfect workmanship which has been attained in structural steel practice.

(6.) The problem of *erection* is much simplified by methods of steel work. Members are assembled and erected by derrick or traveler and are fitted into place with ease and accuracy, and are then bolted or riveted. Hence ease of erection is another very strong point in favor of structural steel.

From the reasons set forth in the foregoing the extreme and indispensable value of steel in engineering construction is apparent.

Nevertheless we have still to deal with the financial question. With the invention of the Bessemer process, the cost of mild steel, as used in large quantities, was reduced 75 per cent or more. making the material financially possible. Further, with the closing years of the nineteenth century came a demand for steel which fully doubled the market for this commodity, conditions imposed on owners of property lying within the business districts of large cities are responsible for the adoption of what is termed the high building. Centralization of business promoted a high increase in land values around these centres such as the "heart of Chicago." Consequently the demand for paying investments and therefore for more floor space led to the erection of the high building, when "skeleton" construction came into vogue. The extensive space occupied by the solid masonry construction was greatly decreased by the structural steel column, and on this account steel became a great financial success.

The items, gentlemen, that I have thus far endeavored to enumerate have been decidedly pro-structural-steel. Within recent years there arose an argument in favor of steel construction which has been more distinctly popular than any, but the fallacy of this very argument forms the connecting link in the evolution of reinforced concrete—I refer to the fireproof question which will be dealt with later.

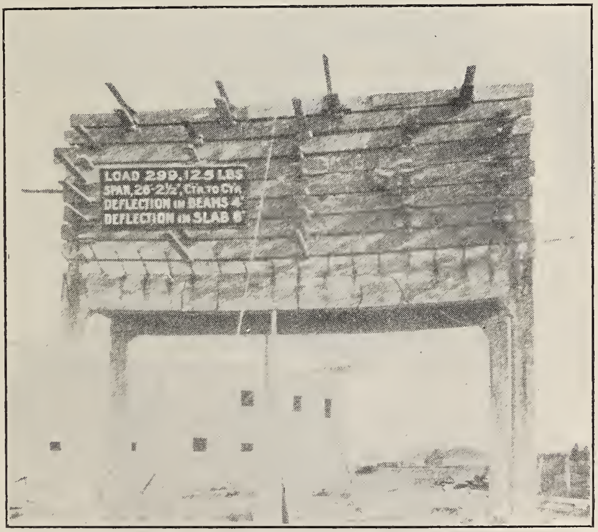
REINFORCED CONCRETE.

Introduction of structural steel took place about a century ago.

Reinforced concrete on the other hand has been known only a decade, and all fair considerations of the possibilities of the latter material must take this into account. The process of establishing reinforced concrete has been similar in its stages to that of steel, but the discussion will be somewhat different. Steel has established itself in popular favor because it has possessed the characteristics above enumerated, but its progress has been somewhat retarded because of its defects of two important particulars, fireproofness and durability.

These have led to the spontaneous establishment of the newer material, which in reverse, strange enough has to battle with the less important but more numerous considerations which built up structural steel.

Considerable theory has been developed concerning reinforced concrete, such as the formulæ of Talbot, Hatt, Thacher and others.



Test of Reinforced Concrete Section, Mimico, Ont.

These calculations are based on the special ability of concrete to withstand compression necessitating the use of only a small amount of steel placed in such a way as to assist the concrete in tension. The theory assumes a condition of no slipping of the embedded metal in addition to some assumptions common to both systems of design. The general reliability of concrete as a material is not as good as that of steel and hence design is affected as regards pure theory. However, most of the manufacturers of steel reinforcement have devised emperical formulæ which are founded on theory and which continued use has verified. The Kahn System state that over $22,000,000 worth of reinforced concrete has been designed and constructed according to their system. We may say then that, theoretically, reinforced concrete is a success.

Resistance to slipping, or the "bond" between steel and concrete is a question of great practical significance. The many patent systems of reinforcement pay more or less attention to this requirement. But the Johnson corrugated bars have been designed with special regard to bond. The surface of the rods is a series of regular indentations or recesses, hence when a reduction in cross-sectional area of the steel due to tension below the elastic limit takes place, bond is preserved. Bond is also strengthened by the method in case of vibration or shock.

With regard to strength, representative tests have served to convince even the most conservative that reinforced concrete has beyond doubt the ability to carry load. (See Fig. 3).

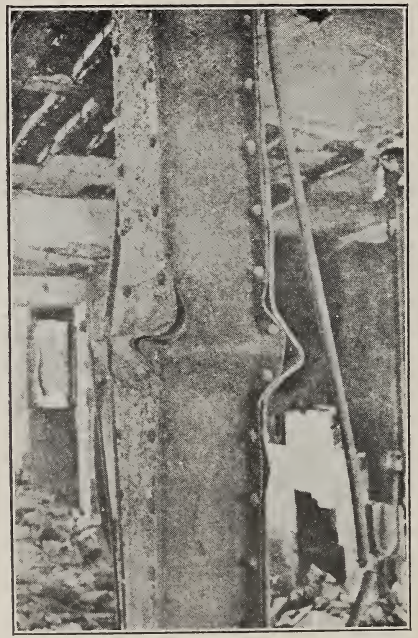


Fig. 4

These experimental tests are substantiated by practical results such as large structures which are actually standing.

It is evident then that reinforced concrete is a theoretical and practical possibility.

Just here I wish again to call attention to the perversity of the discussion of these two materials. In general the reasons on account of which structural steel came into vogue are the reasons in spite of which reinforced concrete remains in use, and the chief reasons for the establishing of the latter are the main objections to the former. Hence it is that in summing up the points concerning reinforced concrete I commence where the steel discussion ended, *i.e.* with the fireproof and durability problems. I should also like you to note that some points for and against steel remain to be evinced by comparison with reinforced concrete.

POINTS IN FAVOR OF REINFORCED CONCRETE.

(1.) *Fireproofness.* Probably the most erroneous conception ever acquired by the public was that of the *fireproofness* of structural steel. Columns of steel in buildings will frequently buckle from excessive heat fifteen minutes after the outbreak of a fire, showing their incapability to withstand the flames successfully.

It has been stated that large timber columns of the ''slow burning form of construction are more fireproof than steel.

However, to offset this, various forms of fireproof protection for steel have been used. Of these, solid porous terra cotta or hollow terra cotta tiles have been extensively applied, but as yet these methods have not proved successful. For example, after the fire in Pittsburg, in May 1897, when the supposedly fireproof steel Horne buildings were completely destroyed by fire the salvage of fireproofing was only 16 2-3 per cent. The failure of such protection has been verified by more recent tests such as the Toronto fire of 1904 and the Baltimore fire. With regard to the latter Mr. Atkinson in his expert insurance report, emphatically states ''terra cotta has failed.'' The same fact was exemplified by the San Francisco disaster; the steel columns, in many cases protected by hollow terra cotta tiles, buckled excessively, while reinforced concrete Expanded Metal floors stood well. In addition, experimental fire tests prove the observations of actual fires; reinforced concrete square columns are not seriously affected for more than a quarter of an inch from the surface or for more than three inches radially at the corners. It is indeed generally conceded that concrete is the only decidedly fireproof material known which is capable of application to engineering purposes. This argument is worth a host of others, and cannot receive too much attention.

(2.) *Durability.* The durability of concrete and its importance as an argument can also hardly be underestimated. It ranks, I believe, equally with that of fireproofness, and the tests are even more convincing. In Rome can be found to-day a number of examples of concrete constructed over 2,000 years ago. The concrete of the Pantheon dome, the House of Vestals, the Aqueduct of Venus still remains, while stone in ancient ruins has long since crumbled away.

The corrosion of steel is well known. Difficulty has been found in obtaining suitable paint even to minimize the powerful oxidizing effect of air on iron surface. However, it is now a well-established fact that steel embedded in concrete is rendered absolutely rustproof. Some writers even maintain that a coating of rust in the steel before placing in the concrete is beneficial. But in any case we may say that the durability of concrete reinforced is strangely enough, twofold; both phases, namely, the durability of the concrete itself and that of the embedded steel, are established by an exhaustive set of tests recently completed by Professor Norton, of the Massachusetts Institute of Technology. The only condition the professor specifies is to "mix wet and mix well." I might add that "the durability of iron embedded in concrete is attested by iron clamps found in the mortar joints in the Pantheon after a period of fully 2,000 years which were in good condition."

The ultra-importance of these two arguments is evident. However there are some others worthy of mention.

(3.) In direct connection with the above comes the argument which is advanced by all advocates of reinforced concrete. That is the low cost of maintenance which is practically nil; while the painting of steel and the higher insurance rate on steel structures increase the cost of maintenance of buildings, etc., of this type.

(4) The monolithic nature of reinforced concrete design is clearly shown to substantially increase efficiency in resisting vibrations such as are caused by machinery, or the shock from earthquakes, etc.

Experiments to determine the results of shocks on various floor systems have been carried on recently by the Paris and Orleans Railway Company. Floors of the steel beam and brick arch construction and of the reinforced concrete system were constructed using the same live load in the design for both. In proportion to the impacts the vibrations of the steel beams and brick arch construction to the concrete construction were 20 to 1 in amount and 11 to 1 in time of duration.

(5) From the contractor's standpoint, steel for reinforcing can be supplied within a few weeks' notice instead of so many months as is generally the case with structural steel orders. I know of one case where the Trussed Concrete Steel Co. supplied an order on two weeks' notice in the busiest season for construction work.

(6) Noiseless construction is often a matter of practical and commercial consideration. The construction of the Marlborough Blenheim Hotel, Atlantic City, was carried on while guests remained in the older portion of the building. The hotel profits would undoubtedly have been impaired by the noisy riveting of the structural steel erection.

(7) Concrete when erected is claimed to be sound-proof.

The above are a few of the many points advanced in favor of reinforced concrete. In the main, I believe I have shown that this commodity, when fabricated, is decidedly an engineering success. However, unlike steel, most of the disadvantages lie with the construction.

DISADVANTAGES OF REINFORCED CONCRETE.

(1) *Workmanship.* The greater portion of the construction of reinforced concrete is done in the field. Consequently the tendency is naturally toward less efficient workmanship. On this

account the work itself is less reliable, also owing to the difficulties met with in "form building" exact and truly finished workmanship is difficult and unusual.

(2) The contractor is subject to varying local labor conditions, to a large extent. The cost of transporting workmen to various "jobs", which are frequently scattered is a consideration of important practical bearing.

(3) From the nature of the construction, difficulty, delay and mistakes in "placing" the steel reinforcement are evidently liable. Hence the chance for properly executed design is materially lessened.

(4) The large amount of lumber used during construction greatly increases the possibility of fire. This is especially objectionable in the hearts of cities.

(5) One of the greatest engineering objections is the difficulty of reliable inspection. Much has been said with regard to this phase of the subject, and it will be merely necessary to refer to it as being one of the most flagrant complaints against reinforced concrete. The difficulties of obtaining reliable inspection may be classed, perhaps, as follows:—

(*a*) Non-uniform testing of cement.
(*b*) Incompleteness of inspecting the mixing.
(*c*) Difficulties in placing, etc.

(6) Every portion of construction has to be moulded, as it were, and moulded, too, exactly in permanent position. Hence the term "clumsy" construction has been applied. The method of raising the concrete members has been tried but is impractical on account of the excessive weight of the concrete.

We have remaining the discussion of the large question of financial possibility of reinforced concrete. The cost is largely increased, of course by these constructional conditions. For instance, the cost of placing reinforcement is about $12.00 per ton of steel. But the all-important item is the cost of "forms"; this I believe will average over 30 per cent. of the total cost of the concrete in a structure. Certain advocates of reinforced concrete claim that its cost is 25 per cent. less than that of steel. I have in mind a building erected according to the reinforced system, and the contractor lost several thousand dollars by underbidding structural steel.

Personally, I believe that the average of reinforced concrete is usually a little in advance of steel. Whether or not this extra financial outlay is warranted is entirely a matter of opinion yet to be shown by the results of more extensive experience.

ADAPTABILITY OF REINFORCED CONCRETE.

Justification for cost is an important consideration and may be better discussed by a brief reference to some specific examples.

(1) Bridges: The fireproof argument hardly applies to bridges. However, durability and resistance to vibration are eminently required, and are attained by the use of reinforced

concrete. But, ''centering'' is usually difficult, expensive and sometimes impossible. Self-support during erection is not feasible and long-span bridges are unusual.

(2) Viaducts: Reinforced concrete is extremely well adapted to viaducts, which must resist vibration, be fireproof and durable. The form work is comparatively simple and uniform and therefore inexpensive. The size of columns in the substructure is immaterial; also, construction is easy since it is mostly executed near the ground in continuous viaducts. Of course the nearer a viaduct tends to become an ordinary bridge, the less do these favorable conditions apply. The above remarks apply more especially to the beam type of viaduct.

(3) Experience has shown reinforced concrete, for the most part, to be well adapted to *culvert* construction.

(4) It is well adapted to *conduit pipes.* The form work is somewhat difficult but uniform.

(5) For dams, reinforced concrete may be well used since durability is here of so great importance.

(6) The *factory building* is one of the very best applications of reinforced concrete on account of the resistance to the vibration of machinery. The size of the columns here is of no special importance since factories may be built in the outlying districts where land space is of little account; also, beauty of construction is not expected in factory buildings.

(7) *Curtain walls* of reinforced concrete are objectionable on account of permeating dampness. This may be partially overcome by the ''Sylvester Process'' which consists of a coating of soap and alum solution.

(8) Probably the best application of reinforced concrete is in *floor construction,* especially for factory buildings or warehouses on account of minimum vibration and great strength.

(9) Finally, *office buildings.* These must be fireproof, hence the demand for reinforced concrete, but here the financial question is important. In the first place the cost of construction is of doubtful economy. Secondly, the size of the columns necessitated by reinforced concrete, brings us back to the original condition which led to the adoption of structural steel in high buildings, namely the saving of floor space.

I will be clear from the foregoing, I think, that very high buildings must needs be essentially of structural steel. However, with the development of the æsthetical capabilities of reinforced concrete it is quite within the range of practicability that buildings up to eight or ten storeys should be erected entirely of reinforced concrete. In this connection the recent invention of a snow-white Portland cement will be significant. The Nottingham Apartments in New York and the Keuffel and Esser building (Fig. 5), Hoboken, N.J., are recent exploits of this nature.

In the discussion of these few remarks concerning two subjects which have in justice proved to be of live issue among engineers, I have endeavored to maintain absolute impartiality, as previously stated. I would urge you, gentlemen, to consider the advisability of acquiring this attitude in all references to the comparative merits of structural steel and reinforced concrete. There is, of course, an infinite amount to be said on this vast subject, but I beg leave to conclude my limited remarks with a brief recapitulation of the points set forth.

The introduction of steel was a matter of slow but steady progress throughout nearly the entire nineteenth century. The extreme physical fitness, combined with large constructive possibilities, and above all the financial success of the material gradually established a position that will probably never be shaken. But the greatest victory was attained by the tremendous tide of popular opinion which staked life and reputation on the supposedly fire-resisting qualities of structural steel. This, combined with the other reasons, of course, raised the use of steel to an altitude only measured by the tallest sky-scraper in New York City. As previously shown, the fallacy of this same idea was the opening flaw which permitted of the inauguration of the newer material, reinforced concrete; and this commodity, strangely enough eminently met the requirements lacking in steel.

Keuffel and Esser Building, Koboken (Fig. 5)

Just here, however, it is of keen interest to note that the arguments advanced are reciprocally opposite in the cases of the two respective materials to which feature allusion has already been made. The fireproofness and durability of concrete in opposition to structural steel is evinced by the liberality of the use of reinforced concrete in the rebuilding of San Francisco, while again, the constructional features are exceedingly poor as opposed to the marked appropriateness of steel work in this connection. We have then a sort of equilibrium of forces acting for and against the two commodities. In brief, the only deficiencies of steel are overcome by concrete and vica versa.

We can all agree, I think, that the points of each material are such that neither arguments may be overlooked. In short, there is a very great deal to be said on both sides. It has seemed to me exceedingly regrettable that there exists at present such intense warfare between the devotees of these two engineering commodities The fight for reinforced concrete has been brilliant, bittter and aggressive and to-day it remains on the market a commodity of undisputed reputation owing to certain abstract qualities such as fireproofness and durability, and in spite of certain drawbacks which tend to render it unpractical. For instance, very high buildings and large bridges can never be other than essentially structural steel.

On this account I believe that the regrettable warfare will result in a happy combination of both reinforced concrete and pure structural steel. The dawn of this era seems to be at hand in the new McGraw building, of New York. Here the columns consist of laced angles with concrete applied principally as a protective attribute. In this, I think, we have the nucleus of a system of construction which will be as near as possible to absolute perfection in spite of the increased original cost, which, by the way, would in the end prove the cheapest. In this connection, floors, beams, and perhaps curtain walls might well be pure reinforced concrete, while roof-trusses, etc., had better remain of structural steel. This combination system, it appears to me will eventually become universal and might justly be called ''Steel-Concrete System'' of construction as a combination of the two systems now distinctly separate.

In conclusion, permit me to say that, in view of the above, I consider it the duty of the future engineers of this country to familiarize themselves with the properties and methods of *both* systems of construction if the general conception of ''broadmindedness, among engineers is to be maintained.

N.B.—Since delivering this address I shold like to express my appreciation of the discussion of these remarks by Mr. Gillespie, Mr. Young, Mr. Chadwick and others; and also of kindness of Mr. Redfern, the Vice-President of this section.

ON THE EFFICIENCY OF HEAT ENGINES

PROF. R. W. ANGUS, B.A.Sc.

Part of the material in the following paper was presented at a meeting of the Mechanical and Electrical Section of the Engineering Society of the Faculty of Applied Science. It is intended primarily for the student, and endeavors to show the desirable, ideal conditions in heat engines, the actual working conditions and the effect produced on the efficiency by using the actual instead of the ideal cycles. If anything in the article will set the student thinking and investigating for himself, the writer will feel himself well repaid.

The development of power from fuels is a matter of vital importance and interest, not only to the engineer, but also in all branches of commerce, partly because of the universal use of power in manufacturing and partly since power may be so readily obtained from fuels which are usually plentiful.

Even in isolated districts this means of obtaining power is quite common, because each pound of coal, wood or oil contains an enormous amount of energy stored up in it. To illustrate this it may be stated that in a pumping station, for every pound of coal used more than 300 Imperial gallons of water may be taken from a lake, driven through several miles of pipe and discharged into a reservoir over 200 feet above the lake. One may get an idea of the magnitude of this result by imagining the work required to raise this same volume of water to the reservoir by means of a team of horses.

Wherever fuels are used, the power is obtained by their combustion, and the heat so liberated is employed in some special form of apparatus which converts this heat energy into some of the forms of mechanical energy. Several kinds of apparatus are used, depending to some extent upon the nature of the fuel, for example the steam boiler and engine or turbine, the air engine, the gas engine and the oil engine. It is of course the object of the designer to make his machine as efficient as possible, that is to make it produce the greatest amount of mechanical energy per pound of fuel used.

Before considering the possibilities of the engines, it may be well to point out some of their limitations regarding efficiency. It was shown by Sadi Carnot in the early part of the last century that when there was only one source of heat and one source of cold, that is one body to carry away the exhaust heat, then an engine worked at best efficiency when it absorbed its heat at the constant temperature of the source of heat and rejected its waste heat at the constant temperature of the source of cold, the change from the higher to the lower temperature being due to expansion without gain or loss of heat, and the change from the lower to the higher temperature also taking place without gain or loss of heat. Thus, suppose a steam engine to be supplied with steam at a temperature of 325° F. and to exhaust at 212° F., then referring to the diagram, (Fig. 1) the engine would be said to work in Carnot's cycle if it absorbed heat from the steam along the line 1—2 at temperature 325° F., expanded without gain or loss of heat down the line 2—3 to the temperature 212° F., exhausted along 3—4 at 212° F., and compressed along 4—1 from 212° F. to 325° F., without gain or loss of heat.

It may be shown that in Carnot's cycle the efficiency depends only on the temperatures of the sources of heat and cold, and not on the nature of the working fluid. Thus if it were possible for a steam engine, a steam turbine, a gas engine and an air engine to work between the *same limiting temperatures,* they would have the same limiting efficiency.

It may be further shown that the efficiency of an engine working in Carnot's cycle is $E = \frac{t - t^1}{t + 461}$ (nearly), where t and t^1 are the respective temperatures in degrees fahrenheit of the sources of heat and cold. Thus supposing a condensing steam

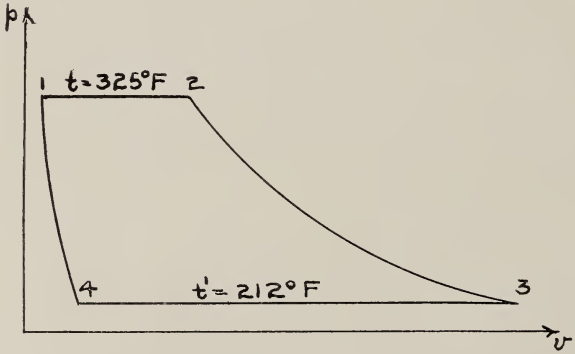


FIG. 1

engine to work with steam at 150 pounds per square inch absolute, and to exhaust at 1 pound per square inch absolute, then the temperature corresponding to the higher pressure is found from steam tables to be 358° F., and to the lower pressure 102° F., (which is also assumed as the temperature of the condenser). Therefore the maximum possible efficiency of such an engine would be $E = \frac{358 - 102}{358 + 461} = .31$ or 31%, since that is the efficiency of Carnot's cycle between these temperatures, and it has been already stated that this cycle represents best efficiency.

The conclusion will then be drawn that for ordinary engines the possible efficiency cannot be extremely high, since it depends on the temperatures t and t^1, which have known practical limits depending on the working pressures and fluids.

The efficiencies referred to above are evidently those based on what is commonly called the indicated power of the machine and do not include the friction of the mechanism, so that the power available at the fly-wheel is further reduced and in the example given would be less than 31% of the energy delivered to the engine by the steam.

Thus far then the following points are to be noted: first, that in any engine, such as a steam engine, we are to expect the maximum efficiency if the heat in the steam is delivered to the engine at the constant temperature of the live steam, and if the heat passes out of the engine to the condenser at the constant temperature of the latter, and no heat is to be supplied or exhausted in any other way during the process., Second, that even when an engine does work under the above conditions the efficiency in practice will not be great, owing to the practical limits of temperature, and most of the heat will be rejected to the condenser and wasted.

Carnot's cycle is of value to us in the study of the efficiency of steam engines because it sets up an ideal toward which we may always strive and shows that this ideal does not depend on the working fluid. From it we learn how we may increase the efficiency of engines by raising and lowering the working temperatures, and also how nearly we have approached the ideal conditions in any case.

THE STEAM ENGINE.

Regarding first the steam engine, as possibly the most common of all such machines, it may be stated that the Carnot cycle is not attempted as the working cycle on account of its impracticability. In steam engines, since the walls are not non-conductors and for other reasons, the transfer of heat to and from the steam goes on for all positions of the piston and therefore at all pressures and temperatures between that of the entering steam and that of the condenser, instead of only at these two limiting temperatures. Moreover, the Carnot cycle is not practicable here because, although the adiabatic expansion from the higher to the lower temperature might be approximated to, yet there is no method of adiabatically compressing from the lower to the higher temperature, and this change of temperature must be made almost entirely in the boiler after the fluid has been delivered to it by the air and feed pumps.

Outside the facts above noted, losses occur due to a very large extent to condensation of the entering and expanding steam.

Considering the illustration already given in which the steam enters the cylinder at 358° F., and is exhausted at 102° F. to the condenser, it is seen that (since the cylinder is made of metal, which is a fairly good conductor of heat) the walls of the cylinder will have a temperature somewhere between these two limits, the exact temperature depending on the amount of steam admitted, etc. The fresh steam thus comes into contact with metal at a very much lower temperature, and therefore a considerable proportion of it will be condensed, and this condensation will go on during the entire period of admission of the steam. The condensation will continue during the early part of the expansion of the steam, and, in fact, until the temperature of the steam, which decreases as it expands, has reached that of the cylinder walls when it will cease,so that during the admission and early expansion there will be considerable loss due to condensation of the steam, and in practice this loss has been found to be very serious. During the latter part of the expansion the steam will be at a lower temperature than the walls of the cylinder, and hence heat will come from them, warning and re-evaporating some of the steam already condensed and returning to the working fluid some of the energy formerly taken out. This return of heat is not so profitable as would at first sight appear, for during the exhaust much of this heat is simply carried away to the condenser and wasted. Another loss results by not allowing the steam to expand down to the condenser pressure, but by discharging it from the cylinder before the end of the expansion period, a process employed to reduce the length of the stroke for a given power.

A further loss occurs at admission because in the ordinary engine the valves usually do not open with sufficient rapidity to allow the steam to enter the cylinder at the pressure in the pipe, and hence the temperature of the steam in the cylinder during admission is lower than that in the steam pipe. Certain losses of heat occur also during other parts of the cycle, but it is impossible to deal with any but the principal sources of loss in a paper of this length.

This brief description shows then that the cycle in the steam engine differs materially at almost every point from the cycle of Carnot, heat being added to and withdrawn from the steam at widely varying temperatures instead of at the temperatures of the live steam and the condenser, so that the cycle of such engines is much lower in efficiency than the corresponding Carnot's cycle.

In well-designed engines the losses mentioned are reduced to a minimum by such devices as Corliss, Mushroom or other quick-acting valves and gears, by compounding, by jacketing and by superheating the steam. Quick-acting valves and gears are designed to open the admission valves so rapidly that the steam may enter the cylinder at the boiler pressure through the full area of the steam ports, and when the desired quantity has been admitted the valves again close as rapidly as possible. Thus there is admission of steam with very little loss of pressure. The continental builders are using with great success mushroom valves, operated by special gears.

Superheating the steam has the double effect, first, of raising the temperature of the steam (without a corresponding increase of pressure) thereby increasing the efficiency of the corresponding Carnot's cycle, and therefore the possible efficiency; second, of reducing the condensation during admission, since by its nature superheated steam may be reduced in temperature at constant pressure without condensation, this reduction in temperature taking place when the hot steam passes into the cylinder, as previously explained.

To reduce the condensation in the cylinder, an obvious plan would be to keep the temperature of the cylinder walls as near as possible to that of the entering steam, which may be effected either by heating the cylinder externally by surrounding it with steam at boiler pressure, that is by jacketing, or else by dividing the total range of temperature among two, three, or more cylinders so that the variation in any one cylinder is not large, and hence the temperature of the entering steam cannot differ much from that of the cylinder walls. This process is called compounding.

Very large engines, such as pumping engines, are very often compounded and have jacketed cylinders and quick-acting valve gears. The new Allis engine at the Toronto Water Works is an illustration of this type, and a brief description accompanied by a diagrammatic sketch of the machine as arranged for the duty trial is here given. In this engine many other devices for increasing the efficiency have been adopted, the most conspicuous of which are the receiver in which the steam is heated between cylinders so that it may contain as little moisture as possible before entering the following cylinder.

The engine is of the vertical, triple expansion, condensing type, having three steam cylinders and three water plungers, each plunger being connected by four vertical rods to the cross-head from the corresponding steam piston. The steam cylinders are respectively 32 in., 60 in. and 90 in. diameter, and 60-in. stroke. Each cylinder is jacketed on the barrel only, the high-pressure jacket receiving steam directly from the main steam pipe through a 1¼ in. pipe and valve. After this steam has passed through the high-pressure jacket it enters the reheating coil in the first receiver, and on leaving this coil passes through a 1¼-in. valve, where it is reduced in pressure, thence through a 1¼-in. pipe to the intermediate jacket. On passing through the intermediate jacket the steam enters the reheating coil in the second receiver. From the second receiver the steam may pass by means of a 1¼-in. valve and pipe to the low-pressure jacket, or it may pass downward through a ¾-in. pipe and reducing valve and trap before entering the jacket; this latter method is the one commonly employed with the engine. From the low-pressure jacket the steam passes through a trap to the atmosphere.

Drain pipes carry off the condensed steam from the steam pipes and the receivers. On starting the engine the condensation in the steam pipe between the throttle and the high-pressure steam valves is blown out through a 1-in. valve and pipe, which valve is then closed and not again opened. Drain pipes 1 in. in diameter are also taken from the first receiver and from the pipes connecting the high-pressure and intermediate-pressure cylinders. This drip may be discharged into the atmosphere, but under ordinary working conditions it passes through a 1-in. pipe, thence in succession through two ½-in. reducing valves, and is finally discharged into the low-pressure jacket through a 1¼-in. pipe. The drip from the second receiver and the pipes between the intermediate and low-pressure cylinders is discharged through a trap.

The main steam pipe is 8 in. diameter, and is divided before entering the engine, one branch of the pipe passing upward, the other downward to the steam valves of the high-pressure cylinder. The exhaust pipes from each end of the cylinder are also united and discharge through a single pipe into the receiver. The other cylinders are similarly arranged except that the low-pressure cylinder discharges into the exhaust pipe, which is 20 in. diameter. This pipe passes downward and is so arranged that the steam may, if desired, be passed through the heater on its way to the condenser, from which the air pump discharges it to the drain.

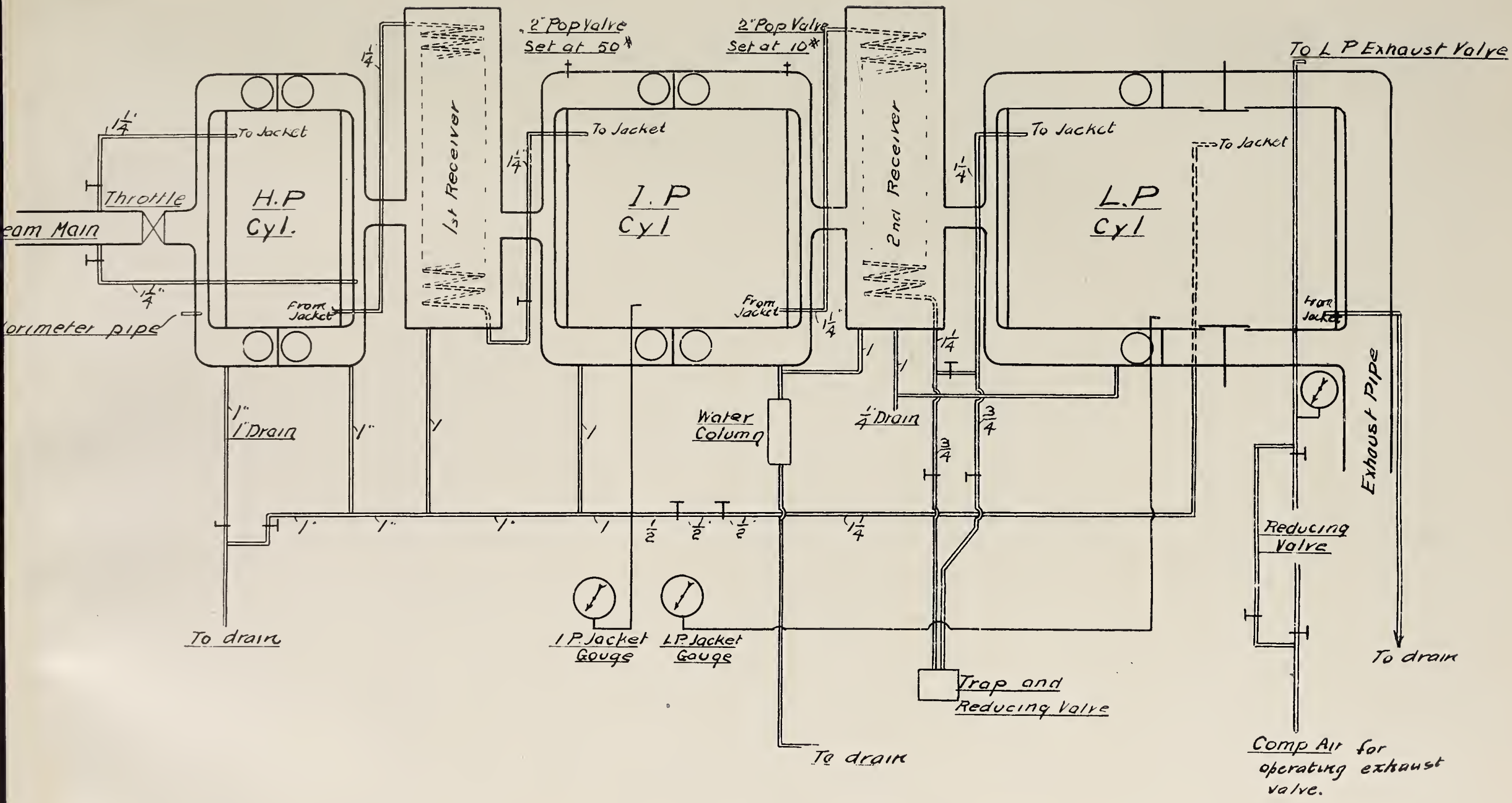
The steam and exhaust valves are placed in the cylinder heads close to the inner face, so as to reduce the clearance space to a minimum.

The design is such that about half of each head of each cylinder is exposed to the entering steam, and the other half to the exhaust steam for the same cylinder. All the steam valves in the engine and the exhaust valve in the high and intermediate-pressure cylinders are Corliss valves operated in the usual way. The exhaust valves in the low-pressure cylinder are flat valves, there being two of these for each end. These valves are opened by the valve gear, the lower pair are closed by gravity, while the upper pair are closed by compressed air.

Such engines as the above give efficiencies when running condensing at about 150 pounds steam pressure of about 21%, which is about two-thirds of that of the corresponding Carnot's cycle.

To convey some idea as to the present state of perfection of the steam engine, the result of a test of one of the most efficient engines ever built my be given. The engine was a quadruple expansion, four-cylinder machine, built by the Nordberg Manufacturing Company, of Milwaukee, Wis., used to drive an air compressor, and the description and results of the test are quoted from a paper by Mr. O. P. Hood in The Transactions of the American Society of Mechanical Engineers, Vol. 28. The steam cylinders were 14.52 in., 22.01 in,, 38.00 in., and 54.00 in. diameter respectively and were all of 48. in. stroke, the speed during the test being 56.945 r.p.m. Special arrangements of a somewhat complicated nature were used to increase the efficiency, a description of which is accurately set forth in the paper referred to. The steam was saturated, and the gauge pressure at the throttle was 242.8 pounds, the exhaust taking place at a pressure of 1.25 pounds absolute.

The temperature at various points may be of interest. That corresponding to the entering steam pressure of 242.8 pounds was 403.4° F.; to the exhaust pressure of 1.25 pounds was 109.6° F.; the steam at the first intermediate cylinder had a temperature of 351.2° F., at the second intermediate cylinder 291.2° F., and at the low-pressure cylinder of 216° F.



Piping of Steam Cylinders of

Under these conditions the actual efficiency of the engine based on indicated horsepower was 25.05%, which was 73.69% of the corresponding Carnot's cycle, the latter having an efficiency of 34%

THE AIR ENGINE.

Let us consider now another type of heat engine using air instead of steam as the working fluid. This type of engine gave promise of good results about the middle of the last century, but owing partly to the great bulk of the engine in proportion to the power produced, the original efficient design has been dispensed with, and the modified, but less economical machine, is built only as a pump for country residences, etc., where a small supply of water is required.

The Carnot's cycle may be attempted in this engine, but since it makes the latter too large, for given power, to be of much practical value, a new cycle was devised in which the efficiency was the same as that of Carnot's cycle, but the engine was much smaller. In the ideal cycle of this type used by Ericsson, the heat is drawn from the source at the constant temperature of the latter, then the change from the higher to the lower temperature takes place by rejecting heat at constant pressure to a device called a regenerator. When the lower temperature has been reached the heat is rejected at this temperature to the source of cold, then finally the change from the lower to the higher temperature is made by absorbing heat from the regenerator at constant pressure. It may be readily proved that in the ideal case the heat rejected to the regenerator is just equal to that absorbed from it, so that the net result in the cycle is that heat is drawn from the hot body or fuel at the constant temperature of the latter and rejected to the source of cold (usually water, as in the condensing steam engine) at the lower constant temperature, thus producing a cycle equal in efficiency to Carnot's.

Several experimenters worked on this type of engine and a description of one constructed by Ericsson and placed on a boat is given in Rankine's "Steam Engine," page 355. The engine had four working cylinders each 14 ft. diameter, 6 ft. stroke, and ran at 9 r.p.m., developing about 300 indicated horsepower. The efficiency of the working fluid (excluding the furnace) was 26.3%, and according to the temperatures assumed by Rankine as probable the efficiency of the working fluid of the corresponding Carnot's cycle would be 33.3%.

THE INTERNAL COMBUSTION ENGINE.

The internal combustion engine would form the basis for many longer articles than the present one, which is already too long, so that all that can here be done is merely to mention it.

The Cornot's cycle is not employed in this engine, but in the cycle most generally employed heat is added to the working fluid at constant volume and hence at varying temperature and pressure, and is rejected under similar conditions, so that the efficiency must be lower than that of Carnot's cycle. Heat is also carried away from the fluid by the jacket water and by radiation at all parts of the cycle.

This engine, however, offers very great possibilities, and with gas fuels efficiencies as high as 30% based on indicated power have been obtained.

In the Diesel engine a very much greater efficiency than the above has been reported, but no comparison is given with the corresponding Carnot's cycle owing to the difficulty of finding the limiting temperatures. Such engines, however, present great opportunities in the way of power development, and they are now being very largely used.

RESISTANCE MEASUREMENT BY VOLTMETER AND DRY CELL

H. W. Price, B.A.Sc.

Not long since, the writer found it necessary to make a large number of resistance measurements at points distributed over a district several miles in length. The resistances varied in value from 2 to 50,000 ohms, and the available apparatus was a voltmeter and a dry cell. It was noticed that results on low resistances were difficult to check satisfactorily, and some little trouble was experienced also with high resistances. Investigation of the formula for calculation of the unknown resistance revealed the cause of difficulty in making accurate measurement. This paper deals with some points of interest in this connection.

METHOD OF RESISTANCE MEASUREMENT UNDER DISCUSSION.

Let R resistance to be measured.

Let r resistance of voltmeter.

Let E reading of voltmeter when connected directly across the dry cell and unknown resistance in series.

Assuming the cell voltage to the same, E, for both observations, the current through the voltmeter during the latter observation is

$$i = \frac{E}{R + r} = \frac{e}{r}$$

whence

$$R = r\left(\frac{E}{e} - 1\right) \ldots\ldots\ldots\ldots \quad (1)$$

If many measurements are necessary, it is convenient to plot a curve of values of R corresponding to values of e, r and E, being constant. A set of such curves is shown in Fig. 1, and from them values of R may be read as readings of e are noted.

SOURCES OF ERROR IN CALCULATED VALUES OF R.

Errors may be due to:

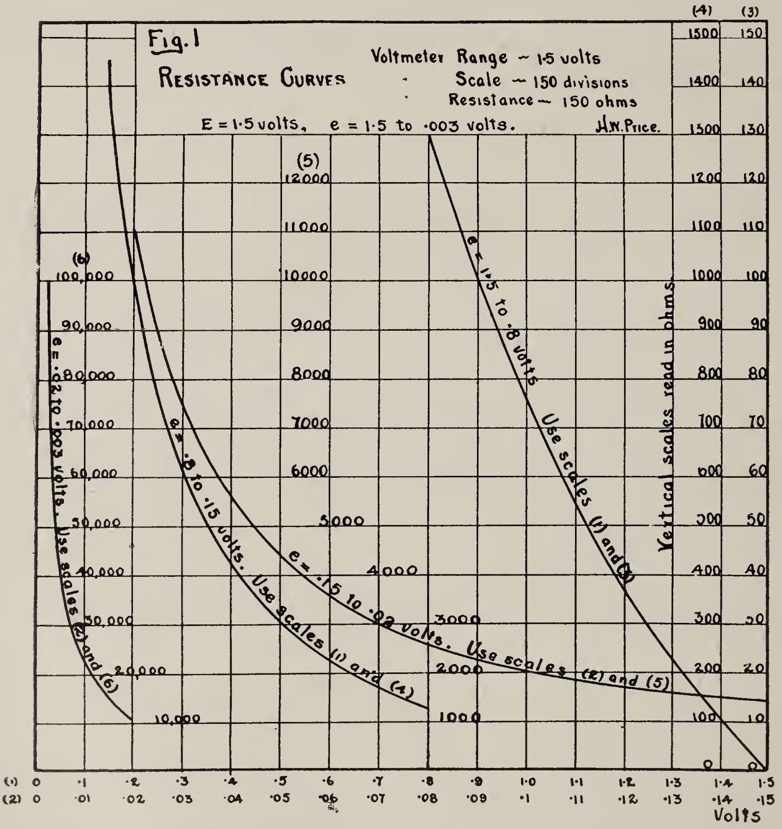
a. Incorrect value for *r*.

b. High internal resistance in the cell.

c. Incorrect readings of *E* or *e* or both.

Difficulties arising from (c) may be due to various causes:

*c*1. The meter calibration may be wrong but the error proportional, that is all indications are the same per cent. high or low.



If the meter resistance were altered to cause correct indication at any point on the scale, all other points would be found correct.

*c*2. The meter calibration may be wrong and the error not proportional, that is, the calibration may be correct at some points and wrong at others.

*c*3. The observer may fail to correctly observe meter indications.

EFFECT OF ERRORS IN DATA ON VALUE OF R.

a. It is evident from formula (1) for *R* that any per cent. error in *r* will create the same per cent. error in the value found for the unknown resistance.

b. High internal resistance of the cell will cause e to be relatively too high. This effect is very small unless the cell is so old that even the slight current required to operate a voltmeter will cause considerable internal drop. A good dry cell should have internal resistance not exceeding 0.1 ohms. A good portable voltmeter requires about 0.01 ampere to cause full scale deflection. With this deflection on a 1.5 volt scale, internal drop is 0.001 volts or only 1-15 of one per cent. of the reading.

When internal resistance is high and unavoidable, it may be allowed for by including in the value for r an item covering cell resistance.

c. From any of the causes listed above, the observation of E or e, or both, may be incorrect. Suppose E and e are observed both too high by an error m and n respectively, where m and n mean fractional parts of E and e, as say 0.01 or 0.02, etc.

The true values E and e are observed as $E\ (1+m)$ and $e\ (1+n)$.

The correct value of the unknown resistance is

$$R = r\left(\frac{E}{e} - 1\right)$$

The incorrect value based on observations is

$$R^1 = r\left(\frac{E\ (1 + m)}{e\ (1 + n)} - 1\right)$$

The per cent. error in R due to incorrect observations is

$$\frac{R^1 - R}{R} \times 100 = \frac{m - n}{1 + n}\ \frac{E}{E - e} \times 100 \quad . \ . \ . \ (2)$$

Since ordinary care will prohibit large value of m or n, the quantity $\frac{m - n}{1 + n}$ may be treated as being practically equal to $m-n$, hence practically the

$$\text{Per cent. error in } R \text{ is } (m-n)\ \frac{E}{E - e} \times 100 \quad . \ . \ . \ (3)$$

This step is the more permissible because it involves approximation not in determination of R but in the error in the calculation.

Conclusions to be drawn from formula (3) are: First, that for given values of m and n, the error in R increases rapidly as e approaches E in value. Second, that if m and n are equal, as occurs with proportional calibration error in the voltmeter described in c1, results are correct, hence are independent of proportional calibration errors. Third, mistakes which cause E to be high, or e low, or both, cause too large values of R, while low readings of E, or high of e, or both, cause too small values of R.

PERSONAL ERRORS IN OBSERVATION.

Suppose a voltmeter scale has 150 divisions. A careful observer can estimate an indication approximately to one-tenth of one division. Let it be supposed that a mistake of one-tenth of a division is possible at any time. The error in observing is at full scale deflection only 1-10 on 150 or 1-15 of one per cent., while at one division deflection the error is 1-10 on 1 or 10 per cent. Hence it is difficult to obtain small readings of *e* accurately and resistances determined therefrom are liable to be inaccurate.

EXAMPLE UNDER SPECIFIED CONDITIONS.

The general formula (3) covers all combinations of troubles resulting in incorrect observations of *E* and *e*, but in order to see clearly the strong or weak points of this method of resistance measurement, it is necessary to consider results from certain specified conditions designed to emphasize the peculiar features of the method without irregularities due to variable errors.

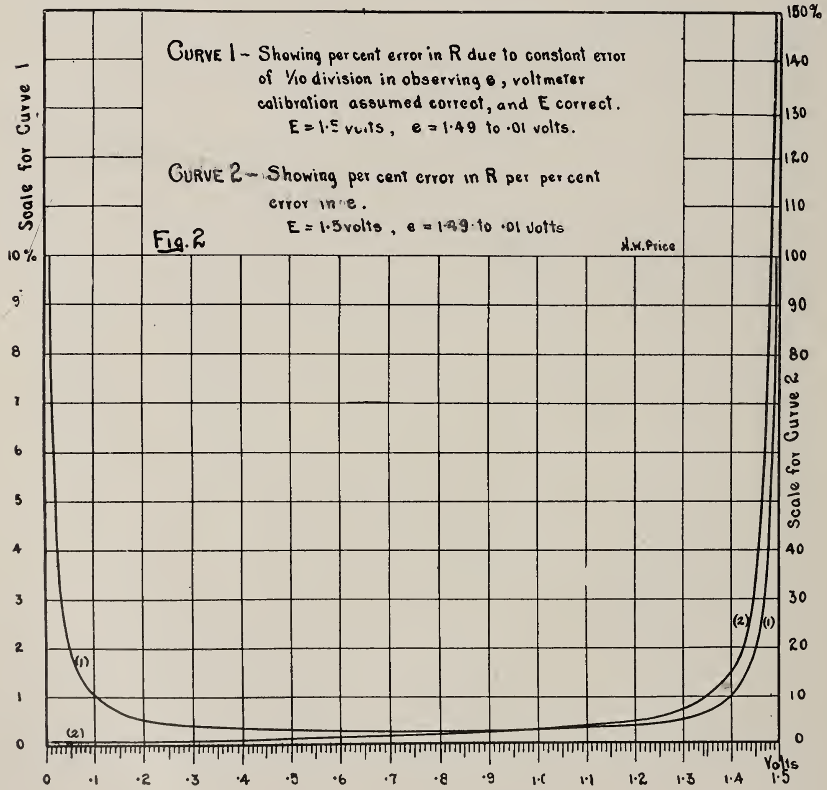


Fig. 2

Assume the use of a dry cell of negligible internal resistance, and a voltmeter correct at all points. Assume $E = 1.5$, and *e* read always 1-10 division low. This will cause all values found for the required resistance to be too great.

The table herewith shows assumed data in columns 1 and 2, and results in 3, 4, 5.

1 Observed Value of E [correct] in scale divisions	2 Observed Value of e [$\frac{1}{10}$ div. low]	3 % Error in Observing e [% low]	4 % Error in Calculated R [% high]	5 % Error in R per % Error in e
150	148.9	.067	10.0	149.
150	144.9	.069	2.07	30.
150	139.9	.071	1.07	15.
150	119.9	.083	.415	5.0
150	99.9	.100	.300	3.0
150	79.9	.125	.267	2.1
150	59.9	.167	.278	1.65
150	39.9	.250	.341	1.36
150	19.9	.500	.577	1.15
150	9.9	1.00	1.07	1.07
150	4.9	2.00	2.07	1.035
150	.9	10.0	10.0+	1.000+

Fig. 1 shows that it is possible by this method to measure resistances from 0 to 100,000 ohms with a voltmeter of 1.5 volt range and 150 ohms resistance.

Fig. 2 shows the reliability of the method under conditions as assumed in the table above and as indicated in the figure. Curve (2) shows the enormous errors in values calculated for *R* resulting from small percentage errors in observing *e*, when *e* approaches *e* in value, that is, when endeavoring to measure resistances below one-third of the voltmeter resistance. Curve (1), however, is of greater interest as representing more nearly the actual value of the method. It shows the resultant effect of difficulties. Small values of *e* cannot be read without considerable per cent. error, and the error in *R* resulting therefrom is of the same per cent. magnitude. Large values of *e* can be read with very small per cent. errors, but per cent. errors in *R* resulting therefrom are so much greater than the errors in *e* that the final result is no better than at the other end of the scale. The maximum accuracy is obtainable when $e=0.5\ E$, that is when the unknown resistance is equal to that of the voltmeter, and at this point an error of 1 per cent. in *e* causes an error of about 2 per cent. in *R*.

It follows, therefore, that the method is most suitable for approximate work, and must be very carefully used for investigating resistances less than say one-half or greater than say six times that of the voltmeter.

NOTE—The above discussion refers only to the properties of one method of using the voltmeter. Small resistances may be quite satisfactorily measured by carrying with the meter a set of small coils of resistances say 0.1, 1, 10 ohms. Choosing the one nearest in value to the unknown, and connecting it in series with the unknown across the dry cell, one can find the unknown resistance by noting relative drops across it and the known coil.

MODERN TENDENCIES IN MACHINE TOOL PRACTICE

WM. SNAITH, '07

Such radical departures from what a few years ago was esteemed standard practise have been made in the machine tool industry that a review of the most salient points in this revolution can hardly be deemed unprofitable. To-day the ''best modern practice in this branch of engineering can hardly be said to exist, for to-morrow's ''standard'' will differ from to-day's as that from yesterday's.

Flexibility and adaptability, with great increases in accuracy and size are the keynotes in the history of the past and present work of the toolmaker. These principles enter into the arrangement of machines in the shop. In place of a large engine and quantities of power-absorbing line shafting there are now small motors driving groups of machines or even single machines. But power itself, in the shape of electricity and compressed air has become exceedingly flexible and portable. Large machine tools are torn off their foundations and carried to the work, following the lead of the pneumatic hammer, the air rivetter and other small tools. Special floor constructions became necessary and the modern machine shop concrete-and-steel floor, levelled within a few thicknesses of paper has become vastly different from the steel-shaving clad plank structure of the past. Portable slotters, planers, millers and boring machines remove the necessity of much transportation and many hours of ''setting up.'' Portable radial drills replace the ratchet, and the cold chisel and hammer are ousted by air tools or portable emery wheels.

In machine tools themselves great changes have been taking place. Milling machines, unknown even in principle a quarter of a century ago, to-day belong to the most highly developed and specialized class. The latter, the oldest of all machine tools exists now also as the principle in boring mills, screw machines and turret lathes. From the polishing and grinding emery wheel has been evolved the grinding machine whose accuracy is beyond the range of the most delicate measuring instruments; originally a finishing machine, a very recent improvement, permits of sufficiently rapid removal of stock to enable roughing to be done equally profitably.

Standardizing smaller machine parts and their production in large lots by means of jigs result in the advantage of interchangability and its attendant economy of time, labor and money. High speed steel, in machines adapted to its use, cuts down time of production and has called for further development of power feeds and automatic stops on the simpler machines. The replacing of cone pulleys by other speed variators and the introduction of change gear sets are responsible for a nearer approach to correct cutting and feeding speeds.

Swaging machines, old in principle and recent in application; presses and sub-presses and many examples of press and die work, with countless lesser features, must be passed over through lack of space. The subject is of more than passing interest and in one with practically, almost necessarily, no up-to-date literature save the advertising pages of the technical press. These are fortunately ample and this sketch will be fittingly close by this reference to them.

A FEW RARE ELEMENTS AND THEIR PRACTICAL APPLICATION

D. J. HUETHER, '08

Mr. President and Fellow Members of the Engineering Society,—I have chosen as the subject for this paper "A Few Rare Elements and Their Practical Application." In preparing this paper I have endeavored to keep two things in view, firstly, to make it of interest to both chemists and miners, and, secondly, not to be too technical. I have, therefore, said nothing as to the chemical methods of preparation and purification of the rare elements that we are about to consider.

I sincerely hope that this paper may be as beneficial to you as the work of preparing it has been to me, and if so I shall consider myself doubly rewarded:

I shall discuss first *Thorium and Cerium and the Welsbach Mantle.*

In the early eighties of last century Dr. Carl von Welsbach while examining some elements of the rare earths by means of the spectroscope, having, of course, raised the substance to incandescence, hit upon the idea of impregnating a piece of pure cotton with the substance and burning it in a bunsen flame; he found that the organic matter of the cotton burned away and left a perfect image of its fabric composed of the oxides of the elements taken. Thus the mantle was born. His first mantles were of zirconia and yttria earths in the proportions to make a normal zirconate. He, however, soon discovered that of all the rare elements, thoria, which is the oxide of thorium, gave the best results; he also observed that the purer the thorium the less the light it gave, and came to the conclusion that the brilliant light must be due to the interaction between the thoria and some impurity. This was finally determined to be ceria.

After an enormous amount of work and experimenting, it was found that the following formula, upon which, as yet, no one has been able to improve, gave the best satisfaction—Thoria, 99%; Ceria, 1%.

There has been endless controversy to explain the action of this trace to ceria. It is supposed that the action is a catalytic one. Ceria acts in somewhat the same way as platinum, for instance, if a ceria mantle is put on a lighted burner and burner turned out and the gas turned on again, the ceria mantle glows and finally lights the gas.

Now as to the manufacture. Thorium and cerium occur in a mineral called monazite sand. This mineral contains about a dozen rare elements. It is mined in Brazil, but occurs also in Florida and California. The monazite contains from 16 to 36% of ceria, but is poor in thoria. Cerium and thorium are extracted by purely chemical means and enter the gas mantle factory as the nitrates of pure ceria and thoria.

It was soon found that cotton, whose ash contained alkalies, attacked and ruined the thoria in the heat of the flame. After a systematic search it was found that China grass was almost ideal for the purpose. It is now grown in India and Southern Italy for the gas mantle industry. The grass for one mantle weighs about seven grams and contains about one-half of a miligram of ash in the form of pure silica free from alkali. It is woven in what are called stockings, for the manufacture of the mantles. The first operation consists in dipping the China grass stocking into a properly constituted solution of thorium and cerium nitrates. The stocking is then passed through a wringer so that only the requisite quantity of solution remains. It is next slipped over a glass form and dried, the object of the glass form being to insure a uniform distribution of the solution. It is next strengthened at the top by dipping its upper end into a solution of oxides of beryllium and aluminum, which when heated form a strong glass. The top is next drawn together so as to form a loop with a thread of long fibred asbestos made in Belgium, thus providing a means of suspending the mantle above the burner.

Next the progressive manufacturer paints his name on the mantle with a solution of uranium nitrate, so that in the heat of the burner his name will appear in the effulgence of the mantle. The shape is still crude and imperfect. It is now moulded in a wooden form to the desired shape. This constitutes the finished product of some manufacturers, the cotton being burned off by the customer when he uses the mantle for the first time, the nitrates becoming the oxides. Others place the mantle in the intensely hot flame of a pressure gas burner to burn away the cloth. It is then dipped into a mixture of copal shellac alcohol, ether and camphor, and dried.

Such is the story of the gas mantle, and it is really marvellous when we consider that they can be sold for from 15 to 25 cents apiece and that in Germany alone 150,000,000 gas mantles are manufactured every year, requiring over 330,000 lbs. of thorium nitrate.

There is another important use to which cerium has been put though not directly connected with the gas mantle, but of interest here because it also was unearthed by the discoverer of the gas mantle. As you all know, one of the drawbacks of gas, compared with electric lighting, especially when you have to grope around in the dark for a match, is that merely turning on the gas does not light it. Welsbach discovered that an alloy of cerium and iron gives off sparks on being scraped or filed. A burner has been designed in which the act of turning on the gas scrapes a little of this alloy, causing a spark, which lights the gas.

Tantalum and the Tantalum Lamp.—Tantalum was discovered by the chemist, Ekeberg, in 1803, while investigating a mineral from Kimito, Finland; what, however, he considered an element was the oxide, $Ta_2 O_5$, which had the remarkable property of being insoluble in all the acids.

Dr. Werner von Bolton, after several years of research and experimenting for a metallic filament in place of carbon, found that tantalum would answer his purpose. He placed the oxide of tantalum between the poles of a powerful electric arc in a vacuum, under the intense heat the oxide is broken up, the oxygen being pumped off as fast as it is formed. In his first experiment he used platinum electrodes and the resulting tantalum was so hard that a sheet 0.04 of an inch thick was drilled by a diamond drill for seventy-two hours at a speed of 5,000 revolutions per minute and was found to reach only 0.25 of the thickness. The intense hardness was found to be due to impurities, the least trace of oxygen or hydrogen, and especially carbon changes its properties completely. He (Dr. Bolton) obtained the pure metal by employing an arc formed between the electrodes of the tantalum first made.

Tantalum when pure is about as hard as the very hardest steel; its ductility and tenacity are high. It can be rolled and drawn into wire of 0.03 m.m. gauge. When in the form of 1 m.m. wire its tensile strength is 132,000 lbs. per square in. The fusing point of tantalum is about 2300° C. The ductility of this metal is taken advantage of in the tantalum lamp. The filament is about 20 inches in length and so very fine that one pound of metal will manufacture 20,000 lamps.

The efficiency of the lamp is about double that of the ordinary bulb light. It may be used on the 110 volt circuit, but does not do well on alternating currents.

Tantalum is now used for the manufacture of dies, drills and pens. It acts on iron like vanadium. It is also used for rectifying alternating currents for tensions below 120 volts. Two electrodes of tantalum plunged into sulphuric acid will stop the current entirely, and if we replace one of the electrodes by a platinum plate the current will pass, but only in one direction. The chief source of tantalum is columbite.

Osmium and the Osmium Lamp.—Osmium belongs to a group of elements which have similar properties. Members of this group are: Ruthenium, rhodium, palladium, platinum, osmium, and iridium.

Osmium has a density of 22.5 in the crystalline state and is the densest of all known substances. It is almost infusible, is very hard and is insoluble in aqua regia.

The osmium light, devised by Welsbach, uses a filament of pure metallic osmium. It is used in the form of a tube which is obtained by coating a platinum wire with osmium and volatilizing the platinum. The life of the lamp is extraordinary, about 2,000 hours. There is no blackening of the bulb. There are several objections, however. It can only be used with a voltage of 47. The filament is so exceedingly fine that it is fragile, so that the lamp can only be used in an upright position. The cost is high. These difficulties will no doubt be overcome in time. It is claimed that the brilliancy of the osmium lamp far exceeds that of the Nernst.

Osmium forms an alloy with platinum, in fact, in nature it occurs as an alloy consisting of osmium, iridium, ruthenium, and rhodium. This natural alloy is very hard and has been used to tip the points of gold pens.

There are also electric lamps employing filaments of zirconium, iridium and tungsten.

The electrical energy consumed by these lamps per candle power is very low; for the tantalum lamp 1 watt per candle power is claimed. The lamps have, however, not been in use for a sufficient length of time to make conclusive claims.

In time, no doubt, the rare elements which are now of only theoretical importance, will be put to practical use and it is to be hoped that some of the credit of discovery will fall to some member, or members, of the class of '08, Miners and Chemists

THE MANUFACTURE OF BEET SUGAR

On Saturday, November 3, through the courtesy of the management, a number of the students in Applied Chemistry had an opportunity of visiting the large factory for the manufacture of sugar from sugar beets, situated a couple of miles out of Berlin, Ont. Every opportunity was given for the students to thoroughly acquaint themselves with the manufacturing process, the genial manager even constituting himself a special guide, accompanying the students through the works and explaining the various operations and processes.

The following is a short account of the beet sugar industry of to-day:—

The manufacture of sugar from beets is not a new process by any means, the industry having been carried on in European countries, chiefly France and Germany, for nearly one hundred years, and now constituting their chief sugar supply. However, its development in America is of comparatively recent origin, the progress of the industry here being largely due to the progressive campaign carried out by the United States Department of Agriculture.

Years of experimental work have shown that for sugar manufacture there are only a few varieties of beets which give the best results. Thus where the climate and soil are not alike different varieties of beets are necessary for best results. Careful study of the best methods of cultivation have also resulted in a greater yield per acre and a higher percentage of sugar, so that where a few years ago twelve and fourteen per cent. of sugar was obtainable beets are now grown which yield as high as twenty per cent of sugar. This is of benefit not only to the manufacturer, but also to the farmer, as his beets are purchased on the value of their sugar content. It is of interest to the chemist to learn that the surest method of ascertaining when the beet is ready to harvest is by a chemical examination of the beet. External appearance of leaf, etc., cannot always be relied on, particularly where the seasons are different.

When the beets are harvested the head, consisting of the leaves and the top of the beet, is cut off. This top contains the salts absorbed by the beet in its growth, consequently if ploughed into the ground soon after harvesting they make a splendid fertilizer, due to the comparatively large proportion of nitrates and phosphates which they contain.

The headed beets, being now delivered by waggon or freight car at the factory, are filled into long bins having sloping sides and along the bottom of which is a flume through which water may be run. By this means the beets may be floated to the factory. They are elevated by means of a mechanical device, which allows the water to drip back, the beets alone being carried up. The beets are next thoroughly washed in a machine having arms which revolve, causing the beets to rub against each other, the dirt and sand which adheres being carried off by the water.

The beets, being now clean, are run to the slicer, a machine having many small knives which slice the beet into V-shaped pieces about an eighth or a quarter of an inch thick and of different lengths.

From the slicer, the cosettes, as they are called, run through a chute by gravity to the diffusion battery. This consists of twelve or fourteen tanks in the shape of upright cylinders, arranged in a circle. In these cylinders the sugary matter in the beet cells is extracted by leaching with hot water. The various cells of the diffusion battery are so arranged that the concentrated liquor is being drawn from one cell while a fresh cell is being filled. The cells are all connected by means of pipes and kept warm by different methods. In the first cell all the sugar is not extracted, probably only half, but as the solution passes through each successive cell it becomes more concentrated till in the last cell it is almost as concentrated as the solution in the cell of the beet. By this means less than one-half of one per cent. of the sugar is lost.

The solution is now drawn off into tanks and heated to about 90° in order to precipitate albuminoid matter, which is soluble in alkalies and which if not removed at this stage causes trouble later on.

The next operation is termed carbonation and consists essentially of treating the liquor with CO_2. The treatment with lime, which is generally performed by mixing about 3% of lime in form of milk of lime, with the solution serves the purpose of neutralizing any acid substance which would help to increase the inversion of the juice. To keep down the amount of invert sugar formed during the process, which is practically lost sugar, is one of the particular cares of the sugar chemist. In addition to neutralizing acid substances the lime also converts the sugar into calcium monosaccharate ($C_{12}H_{22}O_{11},CaO,H_2O$) which as soon as it is formed is decomposed by the CO_2, which is blown into the tank in which the operation is taking place. The CO_2 causes the precipitation of calcium carbonate, which carries down with it a good deal of coloring matter and other impurities, the latter in the form of an insoluble precipitate.

Great care is necessary in the carbonation process. If too much CO_2 be admitted inversion may take place, which, in addition to loss of sugar, causes endless trouble later on in the process. After the first carbonation the juice is passed through filter presses and a second carbonation takes places. In this case about ½% of milk of lime is added and CO_2 passed through till .025 to .05 of lime in the juice is shown, which is determined by titrating against standard acid solution. The juice is then boiled a few minutes to precipitate the double carbonate and again filter pressed.

The liquor is now pumped to the sulphitors, where SO_2 is pumped through. This bleaches the solution and precipitates any lime remaining. From the sulphitors the juice is passed into a quadruple effect evaporator, where the solution is concentrated. This is a cheap and effective method of concentration and is particularly adapted to this use, as the sugar solutions can be heated under pressure at temperatures which are not injurious. Upon emerging from the evaporator the concentrated solution is again treated with SO_2, which has the effect of further bleaching it and neutralizing any impurities. At this point it is sometimes passed through sand or bone black to remove any mechanical impurities and clarify it. The solution is then passed to the strike pan, where it is boiled to the point of crystallization. From this strike pan the granular mass, known as massecuite, and consisting, approximately, of 75% sugar and 25% molasses, is run into crystallizers, which are vessels having moving arms, which, by agitating the mass, assist the crystallization.

From the crystallizers the mass is run by gravity into centrifugals. These free the granular mass of the molasses. The sugar grains are washed in the centrifugals with a small quantity of water. When thoroughly free of the molasses the machine is stopped, the sugar dropped out and carried to a drier. In the drier it is agitated to dry it and prevent caking. It is then passed through a screen to remove lumps, weighed into barrels or sacks and is then ready to be put upon the market.

The molasses obtained, unlike that from the sugar-cane, is dark colored and disagreeable to taste. Consequently it cannot be used directly for consumption. However, it contains about 50% of sugar, and by what is called the osmose process, about half of this sugar can be extracted and crystallized. Owing to the fact that if the molasses is separated from water by an osmotic membrane, such as parchment paper, the salts will diffuse into the water more rapidly than the sugar, advantage is taken of this fact to rid the molasses of some of the salts which prevent the sugar from crystallizing out. Subsequent concentration and crystallization results in the recovery of about half the sugar in the molasses. The molasses remaining is sold to distillers for fermenting purposes.

The pulp which remains after the sugar is extracted is used for feeding stock and also as a fertilizer.

Since both lime and carbon dioxide are necessary in the purification process it has been found desirable to burn the lime at the factory, the CO_2 being then directly available. Hence each factory has one or more kilns in its plant. A necessary feature of the limestone for this purpose is a low contents of silica, since an appreciable amount of this substance clogs the filter presses and is also objectionable in other ways.

As will be realized by the foregoing description, water plays a very prominent part in the beet sugar manufacture, consequently a large supply of good water is absolutely necessary where a factory is located. At Berlin the factory has its own pumping station and it is somewhat surprising to learn that the daily consumption of water at this factory is larger than that of the town itself.

One of the chief drawbacks to the industry at the present time is the inadequate supply of the raw material. At Berlin the factory is in operation for practically three months of the year and the supply of beets obtainable in the immediate vicinity is not enough to keep the factory going for even this time, so that some of the raw material is brought some considerable distance, entailing an added expense.

To the west we must look for the development of the beet sugar industry, and already there is rapid progress being made in this direction. Probably the future will see the factories working, if not the whole year, at least during the greater part of the year, so that we will not have, as at present, many thousands of dollars tied up in a plant which lies idle for the great part of the year.

DISPOSAL OF SLAG AND TAILINGS IN SOUTHERN ARIZONA

A. T. C. McMASTER

While the engineer with a mining and smelting company has many varied and interesting problems to consider in connection with his work, there is one which sometimes receives too little attention This is the disposal of the waste products, the tailings from the concentrator and the slag from the smelter. Among the copper companies of Southern Arizona the methods vary. In the Bisbee district the ore is smelted without concentration, so the smelters of both the Copper Queen and the Calumet and Arizona copper companies, situated at Douglas, have only the slag to dispose of. The country being very flat the dumps are spread out over a large area and moderately heavy grades are used to get greater height for the dumping face. Electric locomotives are used to handle the slag pots.

In the Clifton-Morenci District there are three large companies operating on concentrating propositions. The smallest of these, the Shannon Copper Company, has a splendid side-hill mill-site adjacent to a deep arroyo. Across the mouth of this arroyo the slag from the smelter has been dumped to form a dam and the tailings are run in at the back. This makes both slag and tailings available for rehandling should smelting and concentrating improve sufficiently to make this advisable. It also acts as a large settling basin from which a good percentage of the water used may be recovered at a low pumping cost.

The Detroit Copper Company's smelter is situated in Morenci Gulch and has kept on dumping its slag down the narrow bottom of the gulch, using little or no grade and handling its slag pots by means of dinkey engines. By this means they have obtained a good level site for their power plant which is being continually extended. Their concentrator is well located on the side hill of an arroyo draining into the Longfellow Gulch. Here, in addition to settling in tanks, the tailings are settled in a large basin and the water used again. The difference, however, between this basin and that of the Shannon Copper Company lies in the construction of the retaining wall which is composed of the tailings themselves. The tailings from the dam are distributed along the mouth of the arroyo by means of a launder carried on a light trestle and having ample fall to keep itself clean. Dropping at intervals from this launder the tailings compact themselves and form a firm and efficient retaining wall under all ordinary conditions. There is a disadvantage, however, in this arrangement owing to the cloudbursts and heavy rains which have fallen occasionally in recent years. These pour an immense quantity of water into the pond, filling it and overtopping the wall, which is soon cut away, releasing its burden of water and tailings to work havoc further on. This difficulty, if foreseen, might have been obviated at comparatively small expense in the early stages by putting in a bye-pass for the flood waters.

The Arizona Copper Company have adopted a large concrete settling basin for their new concentrator in Morenci. This is pentagonal in form, and is divided into five compartments each competent to hold a day's run. The tailings drop from a movable launder overhead and the overflow of water is taken off in a fixed launder surrounding the basin. A central revolving crane with clam-shell bucket raises the drained tailings to bins from which they pass up an incline hoist to be trammed to the mines for fill. The moist tailings make a good fill and on drying out become so compact as to make it difficult to drive even a stake into them. A modification of this method has recently been applied to the older concentrators in Clifton, where formerly the tailings were run into the river. There were two causes for this change. The river was frequently unable to carry the tailings away and so they caused the formation of islands and bars which in time of flood appear to have materially increased the amount of damage done to the town and railroad by causing the earlier overflow of the river. The other cause was the objections raised by the farmers in the valley below, claiming that the tailings were damaging their lands. No doubt these damages were much exaggerated as irrigated lands in alkali country deteriorate naturally owing to the working up of the alkali towards the surface.

The tailings from the leacher of the Arizona Copper Company are coarser in size and are mixed with granulated slag from the smelter and used for ballast and fill on the railroads, of which the company owns and operates some 115 miles. As improvements and flood repairs are constantly being carried on there is no difficulty in disposing of this material. The railroad takes the bulk of the slag either in this form or in huge blocks, cooled in the slag cars, for protection against the flood waters. A great deal of protection work has been done with molten slag, also, which has been hauled for as much as four miles and dumped down the sides of the embankments, forming a shell which is not perceptibly damaged by high water unless undermined. At one time the slag was made into slag brick, but that practice has been discontinued.

The utility of saving the slag in some convenient way is shown by the results at Clifton where during the past year a considerable quantity was mined from the old dumps and resmelted. It ran about 8 per cent. copper, which is now a first-class ore in that district.

Another use to which the tailings from certain concentrators may be put is the making of cement. Mr. C. D. Clark, who designed and erected concentrator No. 6 for the Arizona Copper Company, made experiments on and took out patents for the making of cement from tailings. This has not as yet been tested commercially, so far as the writer has heard, and is applicable to certain classes of gangue only; but the cement obtained experimentally from tailings in the Clifton-Morenci District was of very good quality.

APPLIED SCIENCE

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Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ACHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

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Editorial

Concerning the University

The inauguration of R. A. Falconer, M.A., Litt. D., LL.D., D.D., on Sept. 26, as President, signalized the beginning of a new era in the history of the University of Toronto. For a year at a most critical time in the history of the institution its destinies were in the hands of an acting president, Principal Maurice Hutton of University College. It is not idle compliment to say that he performed his onerous duties with a skill and faithfulness that did credit not only to himself but also to the University. It was, perhaps, fortunate that this inter regnum was necessary; for during the year the various faculties became better acquainted with each other, and consequently more sympathetic relations were established.

Principal Peterson, of McGill, at the inaugural ceremonies enumerated a few of the requirements of a successful modern President. He is expected to be not only a scholar and a teacher, but also administrator, organizer, financier, diplomatist and an able and forcible writer, and speaker into the bargain. President Falconer seems to be endowed with all these qualities to a marked degree. A pleasing and forcible speaker, he undoubtedly is; his campaign of speech-making at the beginning of the term put him to a very severe test—a speech or two a day, never the same twice; either new ideas or the old ones clothed in new form, giving always the charm of originality. Of most of the other qualities we must judge from past performances; it is rather early to expect concrete results. Naturally, the Board of Governors have refused to take us into their confidence to gratify our curiosity. The important point, however, is that he has firmly established himself in confidence of all in University circles. There is a feeling which amounts to a certainty that the Board of Governors chose wisely and well, that they selected the right man for the right place, a man who is strong enough to give, and will give, every faculty, professor and student a square deal. His best friend can wish him no more than he live up to his first impressions.

Concerning the Engineering Society

The University started the term with a brand new president. The Engineering Society was even more fortunate—it had a new president and a new constitution. The new constitution was adopted last year but not brought into force till this. In brief, it provided for the division of the Society into three branches: (a) Civil and Architectural; (b) Electrical and Mechanical; (c) Chemistry and Mining. All three sections are controlled by the one executive, but each is presided over by a vice-president, elected by and from the section he represents. The meetings of the three sections are held simultanously and only for the hearing and discussing of papers and addresses of interest to the particular section. All business must be transacted at general meetings, which are, as before, presided over by the president. The meetings are alternately general and sectional. There were several reasons for the change, two will suffice at present. First, the membership of the Society had grown so large (725) that free discussion of papers had ceased; second, the impossibility of getting papers which would appeal to all and consequently the lack of interest or jealousy of those who felt themselves neglected. The new arrangement has worked out well; interest has been sustained and free discussion promoted.

Concerning Applied Science

With the formation of the new sections and the extra papers they furnish, it was felt that the time was opportune for the Society to take a step forward in the matter of its publication. For some years a faculty monthly had been advocated, especially about election times; but for various reasons the scheme floated away with the rest of the planks which make up the driftwood of election platforms. The principal difficulties were lack of someone who could devote sufficient time to manage the project, and lack of funds. Thanks to the Society's supply department, the latter of these was removed, and, consequently, the former. It was felt by the committee in charge that the name "Transactions" was too restricted, consequently after considerable thought and discussion it was decided to publish in future under the name APPLIED SCIENCE. The monthly has been started with the idea of making it, if possible, representative of the activities in and out of the "school" not alone of the instructors and undergraduates but especially of the graduates. We want them to feel as vitally interested in this publication as any student. Efforts will be made to interest every man in every department. Many important experiments and tests are being conducted in our laboratories; they will be described in detail. The papers read before the Society will form the basis of our make-up.

Concerning the Graduates

It is only the loyal co-operation of the graduate body which can make the journal a success. Do something if it is only to kick. A great deal of good is done in this world by consistent kicking, but remember, to produce the best result, it must be administered at the proper time and place. Suggestions will be always gratefully received. If you cannot contribute to our columns, you may be able to persuade some other graduate to do so. Remember, it is hoped to make this thoroughly representative of the activites of graduates and undergraduates. Our graduates are now employed practically all over the world. All will be interested in your work; send in descriptions or information concerning it. Especially just as soon as you notice the standard is not to your liking send us a paper which will help to raise it. The executive of the Engineering Society have many plans for bringing graduates more closely in touch with their Alma Mater, but they must be discussed in a future issue.

Concerning Life Members

The Society has under consideration a change in the conditions for life members. This brings up the question of relations between the present life members and APPLIED SCIENCE. Past executives bequeathed a legacy to us that we find hard to bear. For the sum of two dollars, they agreed to furnish for life all publications of the Engineering Society. When it is considered that issues of the former transactions cost about 50c. each and that after a few years each life member was carried on those conditions at a loss to the Society, it can be easily appreciated that this condition of affairs cannot go on indefinitely. We, therefore, offer Applied Science to all graduates at 50c. per year. If any life members consider they have a grievance under this new arrangement, we shall bind a limited number of copies at the end of the year and send as before.

The appearance of December news in our November issue is rather anomalous, but it is desirable for uniformity in future years to have the volume start in November. As a rule the issues will come out on the first of the month. This year, however, it will be necessary to have two issues in one month.

FROM THE STANDPOINT OF THE UNDERGRADUATE

The buildings are very much over-crowded at present. The Board of Governors are doubtless doing their best to remedy matters. The undergraduates' views of the question are voiced in the following letter:

That which frets the undergraduate more than anything else, with regard to more accommodation, is the fact that there does not appear to be anyone who, up to date, can put his finger on the map and say: ''Yes, we have been considering your case, and are going to commence soon to erect some buildings here for you. They will be ready by next fall. We are mindful of the fact that your laboratory equipment is antiquated, and steps are being taken to remedy that also.''

Can it be a matter of wonder to those in authority that students who have been relegated to the confines of the gymnasium, and tucked away in some corner in the Physics Building, feel that they have a grievance? It is difficult to make the average undergraduate understand that the Board of Governors are thinking, that they are pondering deeply, and many of them becoming thin and pale, over this vexed question. He will invariably answer: ''Yes, doubtless they are thinking; but, surely, they must forget to mark the place, and, in consequence, are compelled to start over again at each successive meeting.''

There is a very strong feeling current in our first year, that the men of 1910 will be ''slated'' at their examinations in consequence of the lack of accommodation. The common question which goes from mouth to mouth, is: ''If they are not going to pluck us, what are they going to do with us? Where are they going to put us?'' Already a great many of our men are wandering off to other universities, since they fear that it will be next to impossible for the Faculty of Applied Science to handle them in a manner that will insure that each individual student gets fair play. It can hardly be denied that many of our junior classes are too crowded. The student feels that he is not in direct touch with the lecturer and is losing heavily in consequence.

Toronto might be considered, at the present moment, the centre of Canada; and, because of its peculiar geographical position, it might be considered to occupy also a very central position in the United States of America. Already our educational systems are receiving notice among our neighbors, and neighboring universities are beginning to recognize in us something more than an ordinary rival. In less than fifteen years, the University of Toronto will number 10,000 students, 2,000 of whom will be engineering students, and with this before us, is it a wonder that some of us are asking anxiously, ''What are you going to do with the little red school-house?''

WHAT WE ARE DOING

A new 50-ton screw power Riehle testing machine has been added to the equipment of the testing laboratories.

A Canadian Rand Compressor has been added to the laboratories. A thorough series of tests will be made on this machine and the results published in a future issue.

The staff received several important additions during the past year: C R. Young, B.A.Sc., lecturer in Applied Mechanics; T. R. London, lecturer in Drawing; A. W. McConnell, lecturer in Architecture.

Dean Galbraith has been with us very little this term. While the Faculty of Applied Science experiences a temporary loss through the Dean's absence, we all feel that the institution has received a world-wide recognition through the appointment of the head of its professorial staff to so important a work as the investigation into the causes of the unfortunate disaster at Quebec.

THE NINETEENTH DINNER

It would be putting it in mild terms to say that the banquet was one of the best. It has always been considered a serious problem to get the first year man to understand his direct relation to the Annual Banquet. This year, however, by force of circumstances perhaps, the first year men learned to know that they had more than a lively interest in this function, and they turned out to the tune of one hundred and fifty men. The executive of the Engineering Society had guaranteed three hundred plates to the caterer, and in their most sanguine moments had hoped that the turn-out would even exceed this number; but, they were not prepared to feed the mouths that belonged to ·880 feet beneath the table. Every available seat that could be placed on the gymnasium floor was occupied; and that those present appreciated the fact that everyone expected to have a good time, was evidenced by the hearty applause which greeted even the most trivial event. The Second Year have established a reputation that they will have to live up to in future.

When the President of the Engineering Society, Mr. T. H. Hogg, rose to give his address of welcome, the round of applause which greeted him showed the position that he occupies in the heart of every true school man. Mr. D. J. McGugan, of 1907, made a strong speech in proposing the toast to the University of Toronto, to which President Falconer replied, and his reception was little less than deafening. The President showed clearly that he was in sympathy with the spirit of the evening, and his remarks, although containing a substratum of seriousness, yet were brightened from first to last by unmistakable witticisms.

Mr. Paul Brecken, of 1908, proposed the toast to the Legislature, which was replied to by Dr. Goggin, of the Education Department, who said among other things, that the Government were beginning to realize at last that the Faculty of Applied Science was now in dire straits for lack of accommodation; and, as far as he was able, gave a promise for the Legislature that they would take some action in the very near future.

The toast to the Engineering Profession was proposed by Mr. John A. Stiles, who voiced the sentiments of the undergraduates in their cry for immediate relief in the matter of more buildings. Mr. T. W. Gibson, Deputy Minister of Mines replied thereto.

Mr. G. G. Mills, in a few choice words, proposed the toast to the Faculty, connecting therewith the name of Dr. Ellis. The Doctor amused everybody, as he always does, with his quaint remarks, making the statement that during the past months when he has been Acting Dean, he has been, as the boys describe it, "making a noise like the Dean." On the plea that this was his night out and that it would be unfair for him to occupy too much time, he brought his remarks to a rather abrupt close, much to the disappointment of every student present, for even the First Year man has heard of the Doctor's after-dinner-speaking ability.

Dean Galbraith made a flying visit to Toronto for the banquet, and was formally introduced to the freshmen by Mr. Hogg. A school banquet would not be a banquet without the beloved Dean being present. One had but to watch the faces of those present to note the interest that was taken in every word he uttered. The Dean said among other things, that as years went by, each making him a little older than the previous, he was inclined to take less seriously the various uprisings of the students, remarking that if the undergraduate insisted on having his fling, necessitating discipline, then he must in the natural course of events take such discipline without a murmur and pay the price. He urged every man concerned in a fracas to come forward after the completion of his fun, and, as it were, surrender himself to the powers that be in order that the Council might have their chance to laugh. The Dean spoke at some length with reference to the Quebec bridge disaster, saying that the pathetic side of the case was brought before him more and more every day and that his sympathies were very much with Mr. Paul Cooper, who was bearing the burden of his great mistake with a manliness which the Dean hoped every engineering student, should occasion arise, would have the power to emulate. The Dean, in conclusion, said that he had greatly benefitted from a much-needed rest which his appointment to the Royal Commission had given him, it being the first real holiday that he had had during nearly thirty years. He, however, voiced the hope that it would not be long until he was back among us again.

The banquet, as a whole, was remarkable for good order and the intense interest displayed in everything; and everyone seemed sorry when the President of the Engineering Society, Mr. Hogg, asked those present to conclude the delightful time spent together by singing "Auld Lang Syne."

WHAT THE GRADUATES ARE DOING

On this page we shall be pleased to publish *professional* news of any of our graduates.

H. S. Carpenter, '97, is Director of Surveys, Province of Saskatchewan.

Fred M. Byam, '06, is with the Riverside Bridge Co., Wheeling, West Virginia.

A. J. McPherson, '93, is Superintendent of Highways for the Province of Saskatchewan.

E. A. Forward is now engineer in charge of the St. Andrews lock and dam, Lockport, Manitoba.

A. H. Arens, '06, is resident engineer, Inverness Railway & Coal Co., Inverness, Cape Breton.

W. E. Douglas, '02, is secretary-treasurer of J. H. McKnight Construction Co., Ltd., Toronto.

W. K. Greenwood is with Willis Chipman. This summer he was in charge of construction of the Simcoe, Ontario, waterworks system.

A. G. Christie, '01, has gone west this year. He is at present Chief Engineer, Western Canada Cement & Coal Co., at Exshaw, Alberta.

The local railways are now appreciating the value of Toronto graduates. E. L. Cousins is resident engineer for the Grand Trunk, while W. A. Cowan holds the same position on the Canadian Pacific Railway.

D. C. Raymond and A. F. Wells, both '04 men, after considerable experience with several large reinforced concrete firms, have formed the Concrete Engineering Co. They have just completed a most successful year's business.

Gerald S. Roxburgh, manager for Featherstonhaugh & Co., Patent Solicitors and Engineers, 17 Canada Permanent Block, Winnipeg, suggests forming an S. P. S. club in Winnipeg along the lines of the one in Pittsburg. The idea is a good one and will doubtless receive encouragement from every "school" man in and around Winnipeg. Since there are quite a number of Toronto men in that vicinity, "Applied Science" hopes to be able to record the formation of the club in some future issue. It would be desirable to unite in some way with the Alumni Association of Winnipeg.

"*A little nonsense there and here,*
Is relished by the Engineer."

E. C. EASY, C.E., HIS THRICE TOLD PROVERBS.

TRIAL LINES

The Engineer is worthy of a higher hire.
Every man is the Engineer of his own fortune.
The most civil Engineer knows some vulgar fractions.
It's a wise Engineer's Club that knows its own Treasurer.
Some are born Engineers, some achieve their C.E., and others have their civility hammered into them.
All's well that pays well.
Great are the uses of Geometry.
The best-made Acts on "Ditches and Water-courses" gang aft agley.
Arbitration is its own award.
A drowning man will catch at a "Nautical Almanac."

FIELD NOTES

Take care of the fence, and the bull will take care of himself.
All is mosquitos that comes through his net.
Where much choke is, there must be some smudge.
A cattle-guard may look at a king-post.
Happy is the bridge that the paint shines on.
A bad bolt is soon sheared.
Where there's a track, there's a right-of-way.
A dead level is better than a live volcano.
A double track is worth a car-load of switch-points.
Bad cross-hairs corrupt good manners.
Assume a bench-mark if you have it not.
All is not Polaris that glitters.
Spare the rod and spoil the profile.
There's many a true North calculated in error.
It's a long road that has no turning-point.
What cannot be guessed must be paced.
A little plumb-bob is a dangerous thing.
There's many a slip 'twixt the sight and the book.
While there's curves, there's "Henck."
Half an oath is better than no chain-bearer.
A transit man's wave is as good as his word.
One man's "Trautwine" is another man's meat.
Swift drains the water where the sewer is deep.
If you give an inch of chance he will take your foot-rule.

OFFICE WORK

Measure in haste and repent in the office.
A night in the town is worth two hundred in the bush.
A steep grade is rather to be chosen than great bridges.
The lawsuit oft proclaims the contractor.

A good rubber turneth away wrath.
The better the description, the better the deed.
What is missed in the tracing will not come out in the blue-print.
He knows not a T^2 from a square root.
Ye canna gather tangents aff a French curve.
When you are at titles, do as the Romans do.
There's no use coloring over spilt ink.
It's a poor scale that won't read both ways.
Faint ink never won fair blue-print.
When Trigonometry comes to the fore, students look out of the window.
Too many cooks spoil the Plot.
Every π has its 3. 14.
One number can be in two places of decimals at once.
It's a poor adder that won't carry his own figure from the last column.
As ye mak your bill, sae maun ye lie on't.

BY-PRODUCTS

A rolling stone gathers no cement.
All are not mines that investors bite at.
Pyrites were deceivers ever.
A grey sand oft makes a red brickyard.
Fine sand betters no concrete.
One layer of expanded metal makes the whole concrete kin.
Airships of a feather fall together.
A wire and its trolley are soon parted.
A telegraph pole is known by its juice.
A touch from a live wire is a breakfast for a coroner.
He who spends on an auto, speeds the highroad to beggary.
Oil is a stranger to friction.
Reforestration is the first aid to Nature.
Radium makes the money go.
It's hard to sit at home, and strive wi' the Pole.
If straps were seats, beggars would ride.
A mad workman quarrels with his crowbar.
A survey goeth before construction, and a power plant before a fall.
Too much anchor-ice breeds lament.
The tail-race is not to the swift current, nor the turbine to the strong.
The flat wheel makes the greatest sound.
It's an ill explosive that blows nobody up.
The promoters flee when no cash pursueth.

Q. E. F.

These proverbs have been printed before, but as Mr. E. C. Easy, C.E., is one of our most distinguished graduates, they are again presented for the benefit of those who were not fortunate enough to see them on the occasion of their first publication.

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THE GEODETIC SURVEY OF CANADA

J. L. RANNIE, '07.

This subject is one which has not been much talked of in Canada except by those who have promoted it so that it likely will be new to the most of my hearers. The subject is such a broad one that many details must here be left out. This may, however, add something to the interest of the paper.

Goedesy is a science which treats of the figure and size of the earth. It naturally follows then that a geodetic survey is one which takes into account the fact that the earth is not a plane but a spheroid.

The need of such a survey has long been felt by this country. The absence of accurate maps has caused the expenditure of thousands of dollars on surveys which would never have been needed had a geodetic survey, and that which naturally follows, a topographical survey been made. A primary triangulation establishes the geographic position of points as far apart as topographical and atmospheric conditions will permit. Secondary and tertiary triangulations fill in important details and the topographical map shows the position of contour lines, rivers, roads, township and all land lines.

Land surveys were commenced in Canada towards the latter end of the eighteenth century and at first consisted of the measuring of tiers of lots along the principal rivers and the shores of the great lakes. As applications for additional surveys were made by incoming settlers township boundaries were surveyed in the localities desired. The subdivisions of these townships into concessions, or ranges, or lots were in some cases the work of three or four different surveyors. Errors rapidly accumulated and as the magnetic needle governed the courses of the lines and the measuring was exceedingly inaccurate the distortion of the townships was very great. The instructions given invariably directed the surveyors to lay out lots of uniform width and the maps returned showed the work as having been carried out according to the instructions. As a matter of fact in some townships in the vicinity of Ottawa, errors amounting to hundreds of feet exist, and in one case a tract of land containing nearly a thousand acres was omitted altogether and the title remained in the Crown until a comparatively recent date.

These remarks apply to the whole of the older or more thickly populated portions of the Dominion and the township maps described have been used for the purpose of compiling the larger maps and are the sole official data available.

I give an extract from the report of the geographer to the Department of the Interior for 1902. Mr. White, alluding to the difficulties of compiling a map of Canada on a scale of 35 miles to the inch, wrote: "The lack of an accurate topographical survey, the numerous sources from which information must be obtained, the difficulty in many cases of obtaining access to the plans of old and almost forgotten surveys, the necessity of incorporating surveys that are being made concurrently with the compilation of the map, which frequently alter the work almost as soon as completed, all tend to make the compilation of such a map a long and tedious operation." Further on in the same report he wrote: "The difficulties in compiling the new map of Canada emphasize the need of a good topographical survey of at least the well settled portions of the Dominion. A few years ago I made a survey between two well defined points on Georgian Bay and the west end of Lake Ontario, respectively, which showed that part of Central Ontario, as shown by the best existing maps, was over two miles out in longitude and over a mile in error in latitude. Although our maps show streams, lakes, etc., even in the extreme north, much of the information upon which they are based is of the vaguest kind."

The advantages of an accurate topographical survey of our country might be set forth as follows:—

(1) Educational.—(a) By promoting an exact knowledge of the country; (b) by serving teachers and pupils in geographical studies.

(2) Practical.—As preliminary maps for planning engineering projects. Highways, electric roads, railroads, aqueducts and sewage plants may be laid out on them and the cost of preliminary surveys may be saved. Areas of catchment for water supply, sites for reservoires, and routes of canals may be ascertained from these maps.

(3) Political.—In all questions relating to political or legislative matters. For these purposes they afford accurate information as to the relations of boundaries and towns to natural features.

(4) Administrative and Military.—In all questions relating to Federal or State administration of public works, as canals, reservations, parks, highways and postal service, and as military base maps on which to place works of offence, defence, camps, marches, etc.

(5) Statistical.—As base maps for the graphic representa-

tion of all facts relating to population, industries, products or other statistical information.

(6) Economic.—As a means for showing the location, extent and accessibility of lands, waters, forests and valuable minerals. In this respect these maps are indispensable to State and Federal bureaus and to owners, investors and corporations.

(7) Scientific.—The triangulation provides the data for the measurement of arcs of meridians or parallels of latitude.

The first step in a trigonometric survey is a thorough reconnaissance of the country for the selection of the most suitable points for the proposed system of triangles. No department of professional labor calls for the exercise of a higher order of ability, or better, repays thorough execution.

Certain general principles must of necessity govern this work, which is one requiring the exercise of skill and good judgment.

(1) Primary triangulation should be carried on with the fewest number of stations which the configuration of the country will allow. The best precision is obtainable by a system of quadrilaterals with every point intervisible; and next by a stem of hexagons where each exterior point sees a central interior station but does not necessarily see every other exterior point.

(2) Primary stations should occupy the crests of ridges or the highest accessible summits of mountain ranges.

(3) While the greatest care should be taken to obtain only well conditioned triangles, yet the only case where the rule of nothing less than 30° for an angle of a triangle should be rigidly adhered to is the case of a single chain of triangles admitting of no check between measured bases.

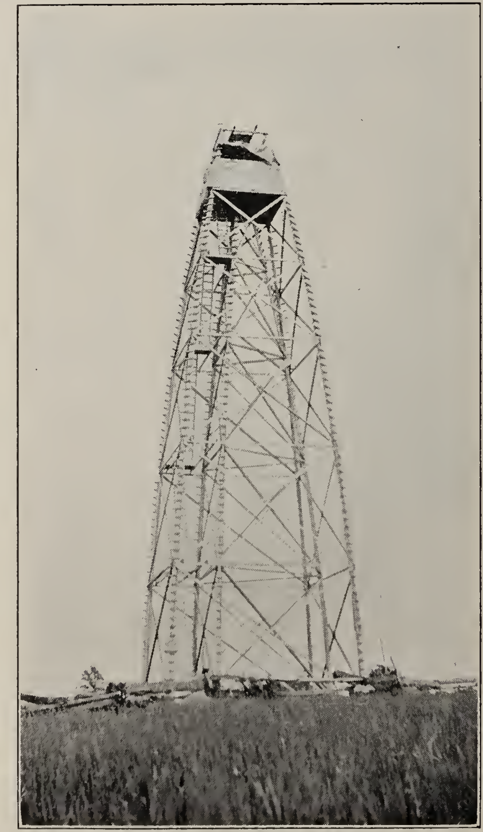
(4) An essential point in reconnaissance is the determination beyond possibility of a doubt of the intervisability of every primary line essential to the scheme.

(5) Permanence of position for primary points, especially near the sea coast, is an object to be carefully looked to.

For a level country intervisability depends much on the distance apart and height of the observing towers. Refraction and curvature is here the factor to be taken into account and the general formula derived in the second applies. It is: Curvature and refraction$=(1\text{-}2m)\ \frac{K^2}{2R}$ where R is the mean radius of the earth; K is distance and m is coeff. or refraction. A shorter form of this is $.574 \times K^2$.

Our operations in Canada have been confined to the district between the Ottawa and St. Lawrence rivers as far as Montreal, and thence easterly across the southern portion of the Province of Quebec to the boundary of New Hampshire, also a triangulation with six angular points connecting two points on Lake Erie with the northern shore of Lake Ontario and including a point in Uxbridge township. The district between a point thirty miles west of Ottawa to Alexandria, about fifty miles to the east, has been found to present many obstacles to triangulation. There is a cession of ridges and depressions lying in an easterly and westerly direction. The ridges are, as a rule, timbered, or at least scattered trees occur, and there are few summits worthy of the name. The quadrilaterals covering the Ottawa district have sides from ten to thirty miles long, and when the angular points were occupied the observer "cut in" all church spires and subsidiary stations where such were necessary. From Alexandria easterly the country is more suitable for triangulation as it is in the main fairly level with occasional very prominent elevations. No observing was done in the Eastern Provinces in the summer of 1907. The triangulation in the west here, which is isolated from the eastern work, covers a comparatively large area of our country, one of the sides of the triangles being 56 miles long, while other lines are longer. The points are: Grand River, near Dunville; Font Hill, near St. Catharines; Binbrook about 15 miles south of Hamilton; a point in Nelson township; Scarborough; and a point in the southern part of Uxbridge township. The first two points are points used by the U.S. Lake Survey.

At the angular points of the quadrilateralts towers are built to make the points intervisible. These towers in Canada are built of wood and the form of construction is essentially the same as the illustration on page 181 of Colonel Clark's work on Geodesy. A footnote on page 180 states that the one illustrated was built by Sergeant Beaton of the Royal Engineers. Although built with the least material consistent with the required rigidity an 80-foot tower contains about 4,600 feet of lumber. They consist of an inner scaffold with three legs, for convenience called the tripod, on which the instrument is placed, and an outer scaffold with four legs on which lights are posted and on which the observer stands. In the erection of the towers one of the legs of



EASTERN ENTRANCE UNIVERSITY OF TORONTO

Supplement Applied Science, December 1907

the tripod is raised first to be used as a gin-pole to raise the other two legs which have been framed together on the ground. Ties and diagonals are then put on and the tripod is used to raise the two opposite sides of the outer scaffold, which are also framed before being raised. A tower is built in about five days. The extreme rigidity of our towers, as evidenced by the accuracy of the results, will be dealt with later. This is, no doubt, largely due to the manner in which the towers are constructed. The curvature introduced into the upright members is so great that their construction necessitates the use of a block and tackle to draw the posts together in order to spike the ties and diagonals. A tent is made to fit around the top of the tower to protect the instrument from the weather.

Beneath these towers permanent marks are placed. They consist of an underground and a surface mark made of 2ft. tile set in and filled with concrete, the point of a 3-16" copper bolt set in the concrete marking the exact spot. The top of the underground mark is placed about 4 feet below the surface and the top of the surface mark about 1½ feet below the surface so as to be below ploughing. Six inches of dry sand intervenes. A reference monument made of concrete is placed near each tower in a convenient fence corner or other out-of-the?way place. Accurate linear measurements are made to it from the centre of th tower and the angle between the line to one of the towers and the centre of the monument is obtained.

The instrument used the past summer was a 12" Altazimuth, made by Troughton and Simms. This excellent instrument was intended and has been used in the past for astronomical observations, and has been used in the past for astronomical observations, being provided with a 12" vertical circle reading by two micrometer microscopes to single seconds. The horizontal circle also reads by two micrometer miscroscopes to single seconds. The only inconveniences about this instrument was its great weight which was a serious factor in getting it to the top of the towers in which work a block and tackle were employed. Lighter instruments have been ordered with three equidistant micrometer miscroscopes and without the large vertical circle. The focal length of the object glass of these new instruments is about 29 inches. It should be noted here, however, that it is questionable if the new instruments will be any improvement on our own, as the extra weight introduced into the English instruments has compensating advantages. Their extreme rigidity and slowness to answer to temperature changes are strongly in their favor for precise geodetic work, while the superiority of graduation of the circle makes up for the fewer number of microscopes.

Lately in the U. S. C. and G. S. triangulations the observer has made all the pointings for horizontal angles by using two parallel vertical lines in the diaphragm of the telescope, placed so as to subtend a horizontal angle of about 20 seconds. The centre of the image pointed upon is placed as nearly as possible midway between the two lines. It is claimed that when all conditions as to brightness are favorable to accurate pointings the same accuracy is obtainable with the parallel lines as with the oblique cross the difficulty of bisecting accurately by eye a space of nearly 20″ being more apparent than real; that in making pointings at night upon an extremely faint image of a light the very faint illumination necessary to make the lines visible will cause the image of a light to disappear when an attempt is made to place the image pointed on very near the intersection of the oblique cross, but the illumination of the parallel lines under the same conditions will produce little effect upon the faint image nearly 10″ away and thus better pointings will be secured. The new instruments spoken of before will have this feature.

The method of observing the horizontal angles is the direction method. Each series of observations consists of successive pointings on the various stations in order from left to right with corresponding readings on the horizontal circle, followed immediately by pointings on the same stations in the reverse order after turning the instrument through 180° and transitting the telescope. The taking of reverse readings cuts out the effect of any error in collimation while the programme of pointings counteracts the effect of any twist in the tripod.

In making the measurements we measure each direction in the primary scheme sixteen times, a direct and reverse reading being considered one measurement, and sixteen positions of the circle are used. These positions are so selected that no microscope ever returns to the same part of the circle which it occupied before. When the observations in sixteen positions have been completed, the circle has been read at thirty-two points scattered over the whole circle at intervals which are about 11°. This insures that the mean value of each angle is almost completely freed from the effect of periodic errors of graduation.

In order to see from one tower to another heliotropes for daytime and acetelyne lamps for night observations are provided. The heliotrope is an instrument for reflecting the sun's rays in any desired direction. At night, when most of the observing is done, one account of the more equal atmospheric conditions, acetelyne lamps are used. The advantages of this light over the oil lamp with a condensing lens in the front are great. Oil lamps usually burn brighter after they have become heated and they are affected more by wind. Also it has been noticed that while the image in the telescope from an oil lamp gradually disappears under difficult conditions as on long lines or on account of haze, by becoming a diffused blur, under the same conditions the light from the acetelyne light becomes a small point of light which finally becomes too small and faint to be observed. Another point in favor of the acetelyne light is its distinctive color.

Two forms of acetelyne lamps have been tried by the Canadian authorities. The one is a modification of the ordinary bicycle lamp. For the front door is substituted an optically good pair of 5″ condensing lenses with a stand to keep the carbide chamber off the lamp stand. This form the writer has found good on lines up to twenty-five miles in length. The other type is the ordinary automobile searchlight with a 6″ or 8″ convex lens and mirror at the back. This has a separate generator and gives a much stronger light than the one previously mentioned.

It was noted above that most of the observing was done at night, when more equal atmospheric conditions prevail. A short note on the difficulties to be met with in daylight observing might prove beneficial. In the section in the vicinity of Ottawa many of the lines pass in some places close to the tops of forests from which refraction is exceedingly irregular in volume and direction. Eccentricities in the closures of triangles have been noticed in the United States which are an indication of the occasional existence of atmospheric conditions fatal to accuracy.

That every precaution is being taken by the Canadian officials to avoid errors due to horizontal displacement of the image under observation is shown by the following extract from the instructions to observers: ''Before attempting day pointing you will please spend at least ten minutes observing with the greatest care the action of the beam of light from a heliotrope, preferably the most distant or the one on the line at right angles to the direction of the wind. Your instrument should be in position on the tripod at least an hour before you make any pointings and the rays of the sun must not be allowed to reach that part of the tripod above the floor. Point your telescope so that the visible image of the beam from the heliotrope is as nearly in the centre of the space between the vertical wires as possible. If you find the vibrations of the image rapid, uncertain but symmetrical in magnitude and covering a small area, careful, deliberate bisections of this area may be made with confidence; but if you observe the image move slowly to one side and return with similar deliberation, even though this movement appears to be methodical, your pointings will be of no value for primary work.''

Another point in daylight observing of primary angles may be noticed from the instructions: ''Daylight readings of microscopes shall be made with the aid of artificial illumination. 'Every-ready' lamps are preferable and they should be held parallel to the graduation that the light may be thrown lengthwise of the grooves and light up their edges equally.''

In a single line of quadrilaterals five signalmen are needed, while in double rows eight are necessary for occupying the central stations.

The duties of the signalman are to post his heliotrope or light and keep it burning and be ready at any time to receive signals for instructions. He is provided with a map showing the positions of the different towers, and a telescope. By placing the map on the lamp stand and orienting it by the meridian he can generally find one of the towers. Then orienting it more exactly by means of the tower found he can point his light sufficiently closely to be seen by the observer who shows him his light whereby he is enabled to make the pointing exactly. The day's work for the signalman begins at 2.30 p.m., when there is sun, and continues till about twenty minutes before sunset, when the lamps are lighted. He goes on his tower about every twenty minutes from then till 9.30 to see that his lamp is burning properly and from that time till 11.30 he stays on the tower and keeps a sharp lookout for signals.

The Morse telegraph code (modified) is used to exchange signals, the dashes and dots being represented by long and short flashes of light, a cover being kept over the light between flashes. Certain code messages are used for messages which are frequently sent by the observer, such as:

T H D—I am finished with you for this half day.
D G—followed by name of station—Done, go to station named.
S T—followed by name of station—Show to station named.

This method of giving instructions saves an incalculable amount of time and also of money as the mails are slow and telephoning expensive.

Reference has been made to the rigidity of the towers as evidenced by the accuracy of the results. The instructions given for the summer of 1907 required that the means of the four groups of four positions each should agree within two seconds of arc and that the closing error of the primary triangles should not exceed one second. The spherical excess may be computed approximately by the formula: Sph. excess = 1″ of arc for each 75 sq. mi. of area. That such results were obtainable even in a wind with a velocity of fifteen to twenty miles an hour is sufficient proof of the rigidity of the towers. In this connection it may be said that United States C. & G. S. instructions require the closing errror to be within three seconds.

Just here a short discussion of linear measurements suggests itself. A paper on a Geodetic Survey would be incomplete were this subject ignored. From the inception of goedetic surveys the measuring of base lines has probably received more attention than any other part of the work. Extreme accuracy in this respect has until quite recently been considered of primary importance, it being considered better practice to introduce base lines measured with less accuracy at shorter intervals. The refinements of least squares computations are mainly responsible for the conclusion that the errors in the triangles composing the base nets between the comparatively short base lines and the longer sides of the quadrilaterals are largely in excess of any other class of errors, and all angular measures are of inferior accuracy when compared with linear measures. Hence it is considered better practice to select the ground for the base lines after the observing towers have been built so that the expansion may be as direct and perfect as possible. In carrying on later work in the United States the practice of introducing base lines at comparatively short intervals has been followed and in their latest work the mean distance has been one hundred and seventeen miles.

Previous to 1906 base lines have been measured with tape lines which were referred to a comparator one hundred meters long, the length of the latter being determined by the iced-bar apparatus. This system has been used for many years but its efficiency has been materially increased by the use of Invar tapes. Invar is an alloy of 64 parts steel and 36 parts nickel, or thereabouts, and tape lines of this material may now be obtained in London. The temperature coefficient is smaller than that of any other known substance and tape lines of this metal are guaranteed not to contract or expand more than 1/1,250,000 part of their length for each degree centigrade or about 1 inch in 20 miles. Steel tapes require a correction of about fifteen inches in twenty miles for each degree centigrade. With regard to Invar the above figures are the maximum. The average results of tests of that metal show a coefficient of about 1/4 of the above or one inch in eighty miles. The accurate determination of the temperature throughout of any measuring apparatus has always been considered a most difficult problem. Scientific experiments have accomplished much in this direction but Invar has practically removed the necessity for further inventions or experiments in connection with measuring apparatus. Heretofore all tape line measurements of base lines have been made at night for obvious reasons. Field experiments and comparisons have shown that Invar tapes may be used in the daytime with absolute confidence and when properly standardized may be employed without the comparator, thus doing away with the iced-bar apparatus in the field.

A base line about seven miles in length near Coteau Jc., P. Q., has been selected but not measured with accuracy. The directness and perfection of the expansion from the extremities of this base to the sides of the main triangulation show the advantage of selecting the ground for base lines after the triangulation points have been occupied and brings great credit to the judgment of the official in charge.

The fact that Canada is only commencing work that has been in active progress in other countries for more than a century is not a subject for congratulation. There are, however, many palliating circumstances and in some respects we gain materially as we have the enormous advantage of the experience of other countries. We have also the benefit of comparatively recent inventions which aids to accuracy.

Now that we are making a primary triangulation which is the only scientific method of connecting detached surveys we may reasonably expect that other much needed surveys will follow until Canada will have maps of the country of which she may be justly proud. The progress of the work during the season of 1907 was very satisfactory considering the delays and the size of the staff.

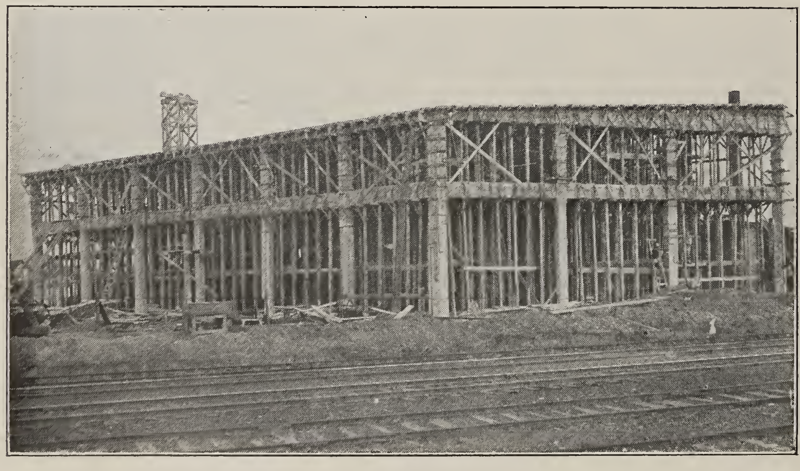
In preparing this paper I have had recourse at several points to a paper given before the Ottawa Section of the Royal Astronomical Society by Mr. C. A. Bigger, the official in charge of the Geodetic Survey of Canada.

COST OF A REINFORCED CONCRETE FACTORY BUILDING

D. L. C. RAYMOND, B.A.Sc., '04.

The importance of keeping accurate cost data in reinforced concrete construction is frequently underestimated by the contractor. In order to tender intelligently on similar work the recording of costs of labor in erecting forms, mixing and placing concrete, is especially important.

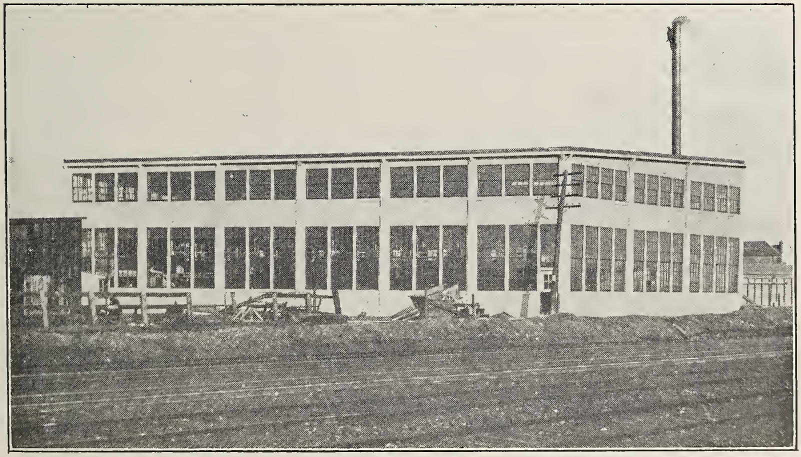
Fig. 1 shows a reinforced concrete factory building recently erected at Walkerville, Ont. It is 100 x 100 feet two-storey building, with a gore extending 55 feet along one side. The ceiling heights are: First floor, 18 feet; second floor, 12 feet. The building was designed in skeleton construction, the windows extending from column to column, insuring a well lighted interior. The curtain walls, which were made 6 inches thick, were capped with concrete sills. The typical floor panel, 16 x 16 feet, has two intermediate beams. Kahn Cup Bars were used to reinforce the footings,



McGreggor, Banwell Fence Co., Walkerville, Building under Construction columns and beams, the floor slab being reinforced with Ideal wire reinforcement.

The mixing and hoisting equipment consisted of a No. 1 Smith batch mixer, capacity 10 cubic yards per hour; one boiler, which provided sufficient power for both hoisting and running engines, and a Ransome bucket in which the concrete was elevated to upper floor and roof. A hopper with a cut off into which the bucket dumped automatically prevented any delay while concrete was being poured.

The column and beam centering consisted of 2 inch Norway pine, dressed four sides. Considerable labor and expense was done away with by using iron clamps for column and beam boxes. The beam centering was supported at intervals of two feet by 4 x 4 inch cedar posts, crossed braced, under which maple wedges were placed. The floor centering was built of 1 inch Norway pine, dressed one side, laid on 2 x 4's, 18 inch centres, supported by strips on sides of beam boxes. To keep the carpenters continuously employed the column and beam boxes were prepared while the concrete footings were poured; these were afterwards erected and framed.



McGreggor, Banwell Fence Co., Walkerville, Building Completed

A mixture of one part cement, two parts clean sharp sand, and four parts gravel to pass a one inch ring was used for concrete. The one inch finish was laid with floor and consisted of one part cement to two parts sand.

The following figures are based on cost data kept during construction. It will be noticed that the cost of centering seems high, while the cost of reinforcement is very low. This is due to the short span construction necessitating two intermediate beams which accordingly increased the carpenter labor and amount of lumber used. This was more than offset by the saving in reinforcing material.

The laborers were all new to this class of work. Operations commenced Sept. 3 and the building was ready for occupancy Dec. 1st.

In all 847 cubic yards of reinforced concrete were used in construction. The total cost being $16,829.03, or $19.88 per cubic yard. The cost was made up as follows:—

MATERIALS.	TOTAL COST.	COST PER CU. YD.
Cement at $2.05 per bbl...........	$3,314 08	$3 91
Sand and gravel at $1.25 per cu. yd.	1,053 85	1 25
Reinforced at $55.00 per ton.......	2,314 08	2 75
Centering, 4x4 cedar at...$25 per M.		
2x4 N. pine... 27 per M.		
1 in. flooring.. 28 per M.	4,943 70	13
Nails, etc.	106 84	13
LABOR		
Building runs, hoisting and mixing concrete	872 00	1 03
Placing and tamping concrete......	562 00	66
Placing reinforcement	221 00	26
Stripping, centering and cleaning up	379 93	45
Carpenters building and setting forms	2,009 55	2 38
Superintendence	714 00	84
Tools and depreciation in equipment	338 00	40
	$16,829 03	$19 88

REINFORCED CONCRETE

L. G. ROBINSON, E.E.

Mr. Chairman and Members of the Engineering Society:

It affords me great pleasure to meet you in this manner. Your committee on papers (let us call them the reception committee) have introduced us to each other and have provided a topic for conversation, viz:—Reinforced Concrete. The subject is an interesting one from an engineer's point of view, for, by the very nature of his business an engineer must be an economist of the highest type. It is his duty to find out all he can of the characteristics of the material available for his work and assign to them the degree of importance each has by reason of its particular characteristics, availability, cost, etc., and then use them in such manner as to bring about the greatest good.

The ideal engineer is therefore an economist who exercises a high degree of "common sense" in the use of the laws of nature for the benefit of mankind.

Now, concrete is a well recognized common material of construction. Its use dates back into a remote and indefinite period, when it simply meant to the engineer so much artificial stone or rigid material of unknown strength and physical properties. It was used principally in great bulk for the sake of filling space and giving a firm foundation for structures of great weight, and it is even so used today, being one of the most pliable and easily worked materials for the purpose. About one generation ago, however, the engineers of England, France and Germany found that it was necessary to tie this material together by means of anchor-rods. It was discovered that concrete was subject to irregularities in its construction which caused in it fine cracks, fissures and seams, and apparently there was no law which governed the formation of these faults. The first idea which appealed to them in this case was therefore to insert steel rods or iron bars wherever they expected that the concrete would be subjected to any other stress than direct compression. There, gentlemen, was the genesis of reinforced concrete.

About this time theorists, mathematicians and engineers at the head of their profession began to enquire into the nature of the stresses and strains existing in beams generally. It did not take many years of research to find out that the internal stresses were very highly complicated. One theory after another would be propounded only to find that the hypotheses and the equations derived from them did not fit the case. And so hundreds and hundreds of experiments were performed in order to find out, if possible, what law existed. Needless to say none was found, therefore, empirical formulæ were established, some of which are in general use even today.

By this time the use of iron and steel was quite common. Steel and iron have always been expensive for the reason that it was such good material that the demand has always kept pace with the supply. In order to economize in the use of this material, investigation went on a pace. The empirical formulæ were revised time after time and, finally reached the degree of refinement which exists today.

It was found, however, that even steel had limitations which made it to some extent undesirable in permanent structures. It had to be protected from rust, fire, electrolysis and various other things. In searching about for the means of protection it was found that concrete enclosing the iron would successfully prevent the occurrence of most of these things to a large degree. It occurred to a few engineers at that time that a composite structure made up of steel rods and concrete would serve the same purpose as an entire steel structure incased in concrete and be much more economical. This then was the beginning of the *modern* form of reinforced concrete. Structures built in this manner were of a necessity heavy and massive. No attempt was made to reinforce concrete for anything other than direct tension. The economy which was *expected* was not wholly realized. Efforts were then put forth by the investigators to reduce the weight and size of this type of structure. By frequent tests of sample beams made up in this manner it was found that concrete almost invariably failed from shear. To prevent this they resorted to the placing of small rods in a vertical position in the concrete in such manner as to take up the internal shear stresses. This was called, at *the time*, a complete success.

As competition, however, became sharper it was found to be necessary to *still further* reduce the cost of this kind of work. From this time to the present day the quality of Portland cement has been steadily improving. The tensil strength of neat cement at that time was considered *excellent* when it withstood 250 lbs. to the square inch. At the present time it is not uncommon for a briquette of one square inch cross section to be unbreakable in a 1,000 lb. testing machine.

Now, to my mind there is nothing which will stimulate effort as much as a partial success. Twenty years ago reinforced concrete was called successful by a *few*. Its possibilities gradually dawned upon the engineering public, and it seems that every structural engineer made a tremendous effort to secure the advantages to be gained from the use of such a promising building material. Even the governments of several countries carried on extensive investigations in order to adapt it to their uses. The French Government found that when the rods used for reinforcing concrete for shear stresses were made fast to the main tension reinforcement the strength of a beam could be thereby increased about 20 per cent. As soon as these reports were published, private investigations also were largely directed in that way. Whenever such investigation proved satisfactory to the individual, the form which the shear members and tension members took, and their relation to each other was called a "system." At the present time *systems* have multiplied until, it is safe to say, there are at least twenty systems in common use. Now, here again exists a problem for our ideal engineer. Which system shall he use? Is it necessary for him to go over all the ground covered by the various investigations, both public and private? I think not. The reports of these various systems and of the work carried on at the government's expense furnishes abundant information upon which he can base his opinions. Let him first go back to the mathematician's analysis of the stresses in beams. Get these firmly fixed in mind so that when going over the multitude of suggestions and arguments for and against the different systems, he will not lose sight of *his own* conception of the nature of the stresses in a beam.

Let us try and see if we can get an idea of what this conception would be in the case of a simple rectangular bear supported at each end and subjected to a load.

The first idea which occurs to the analytical mind is that unless he beam is rigid it will bend or break under the load. Now, we all know that there is nothing in the world which is absolutely rigid. Our beam is, therefore bound to bend and in bending, the lower portion of the beam will be subjected to tension. On the other hand the upper portion of the beam will be subjected to compression. At some plane lying between these two conditions there is no stress whatever of tension or compression. This is called the natural plane or neutral axis.

The next idea which presents itself is that the upper portion being in compression and the lower in tension these two forces must be in opposition to each other in order to preserve equilibrium. Hence, there must be a tendency for the upper portion to slide upon the lower portion. This we call longitudinal shear. A good analogy would be to imagine two boards one laid upon the other flat upon supports at either end and a load placed upon the middle of them. They will bend, and it will be noticed that the upper board actually does slide upon the lower board in a longitudinal direction so as to extend beyond it at the ends.

Again, there is another tendency for each of the supports to push off a piece of the beam in a vertical direction. The combination of this force and the longitudinal shear, resolved into one by the parallelogram of forces, will result in a force which is neither perpendicular nor horizontal but inclined to these approximately 45 degrees. If the material in the beam is not strong enough to withstand this force it will part in a plane which is perpendicular to the direction of the resultant at each point of failure.

Now, whatever may be the conditions of loading these three actions take place in *every* beam, and their relative amounts are according to the conditions of loading. In order to prevent the failure of a concrete beam, the reinforcement must be so designed as to successfully sustain these stresses at all points. In most cases the conditions of loading vary. A structure may be partially loaded, fully loaded, or the load may be concentrated at some point or points, or it may be uniformly distributed over all the structure.

The judgment of the designer here comes into play and it is *impossible* to eliminate at this point his *personal equation.* He will have to study the conditions which will be imposed upon the structure and so proportion the combining parts of the same in such a manner as to take care of the most severe conditions to be expected. Obviously, then, he must have a system of reinforcement at hand which is so flexible in its nature that he can readily dispose the steel throughout the concrete as to meet with his requirements without undue elaboration or expense.

Economy calls for the disposition of steel in such a manner that there will not be an *excess* at any point above what is required to resist tension and shear of the concrete. As to compression, the value of the resistant powers of concrete are very well known and it is an easy matter for one to provide ample proportions to meet with this requirement.

Steel in the form of rods or bars will satisfactorily sustain tension and its ability to do so is also well known. The question is not very difficult when only the tension in a beam is to be considered, but how to dispose the steel in such a manner that in *tension* it will successfully resist the *shear* stresses of the structure is the *crux* of the *whole matter.* Upon this point is determined the merit or de-merit of all the various systems for reinforcing concrete.

We are ready now to draw conclusions. In the light of the above analysis and discussion we are able to say what shall be the *principal characteristics* of a reinforcing system which shall be best adapted to construction:—

1. There must be a Main Tension Member.

The variation of the strength of this member must be easily accomplished.

The size and shape of this member should not be such as to make it difficult to thoroughly imbed it in concrete, for in order to allow it to develop its whole strength and efficiency in the structure it must be so intimately in contact with the concrete that it cannot slip longitudinally. Right here it may be said that numerous experiments have been recently performed for the purpose of finding out how much grip may be depended upon between the concrete and steel. It was found under various conditions that a good wet mixture of concrete would develop a surface cohesion amounting to from 210 lbs. to 450 lbs. per square inch superficial area of the steel. This feat depends so much upon the workmanship that it has been found best to impose a generous factor of safety. It is the custom to expect a working adhesion of 50 lbs. per square inch.

The form of the steel should be such as to make it quite easy to attach the shear members to them; this will be determined largely by the *method adopted* for the attachment.

2. There must be Shear Members.

They must be so placed that when acting in tension they will resist shear stresses.

They should be attached to the main tension members.

This attachment should be such that the shear members may be placed in position at any point along the beam and as frequently as desirable.

One should be able to incline them to any angle and make them of any length to suit the structure in which they are to be placed.

They should not be very heavy. On the other hand, they should be as light as it is possible to work them; for, the stresses which they are to take up are by nature *distributed* stresses, and, so the greater the *number* of them interspersed throughout the concrete the more perfectly will they take up the stresses as they exist in the beam.

3. From the standpoint of economy, availability, cost, etc., the steel of which this system is made up should be of such forms as are usually obtained in commerce, i.e., *commercial forms.*

TECHNICAL PHOTOGRAPHY

G. R. ANDERSON, M.A.

The statement has often been made that the nineteenth century witnessed a development of scientific knowledge and the application of science to art and industry surpassing the aggregate of all previous progress, and when the field is carefully surveyed few will doubt its truth.

Amongst the multitude of scientific discoveries that have made the past century so famous probably no single one can show a more brilliant record than photography, whether it be judged merely as a series of successful researches in the domain of chemistry and physics or by the range and importance of its applications.

Progress in the early days was somewhat slow and when we remember that the first crude plates of metal coated with asphaltum required ten hours exposure, it must be admitted that the outlook was not very promising. A few years later the secret of the daguerreotype was made public by means of which process a picture could be produced by an exposure of a few minutes. These processes, however, were both positive, the picture being in each case a finished product from which duplicates could not be made.

The introduction of the glass plate fifty years ago on which the negative is produced and from which an indefinite number of positive prints may be made was a revolution. True, the collodion wet plate was troublesome to work; it had to be exposed and developed before it had dried and so necessitated an outfit of chemicals that prevented its use except in connection with a dark room. The results obtained were, however, satisfactory, and the art of photography was assured of success.

The perfecting of the gelatine dry plate forms another landmark in progress by which the elaborate outfit of chemicals hitherto necessary was dispensed with and the photographer was able to take a stock of prepared plates to any place desired, make the required exposures, and complete the development on his return.

The closing years of the century saw important advances made in orthochromatic and color photograph, in the discovery of new printing processes, in the introduction of cinematography, or the photography of motion, and in the perfecting of the lens and mechanical equipments of the camera that make it a model of perfection among scientific instruments.

From the time of the first photographic discovery the problem of photomechanical printing has been constantly in the minds of experimenters. As early as 1842 an attempt was made to produce an electro plate from the daguerreotype, and in 1843 a process was patented for etching the same with acid. These attempts were not very successful, but some fifteen years later the Woodbury process of printing from a gelatine relief was perfected and in a modified form is still in use. A great variety of photo-engraving processes have followed so that results are now obtained in monochrome and color that it would seem hard to improve upon, showing that this phase of the work was quite kept pace with that of photography itself.

In the mind of the general public photography is associated mainly with two classes of operators: the "professional," who occupies a studio and whose work is confined almost entirely to portraiture, and the "amateur," with his kodak, who snaps anything and everything in sight. But while these two classes occupy a large share of attention by reason of their numerical strength, they by no means occupy a large portion of the field of usefulness open to the art. The work of photography for newspaper and magazine illustration alone is enormous, and if directed in a proper way becomes an educational factor of prime importance. In the realms of pure science photography has been of the utmost value in promoting scientific research, the eye even of the trained observer is prone to err and a multitude of details cannot be comprehended at once, but a photograph is a true record which can be examined at leisure and compared with the results of future experiments. The camera may be combined with the microscope and telescope, and the photographic plate made to record with equal facility the structure of the minutest organism or the constellations of the fixed stars.

To what use is photography put in the theory and practice of engineering? and what is the outlook for its increased application? It has been said that "drawing is the written language of the engineer," and may it not be added that "photography is his short-hand"? While it may not supersede drawing it may supplement it in many ways. In the laboratory tests of almost every description may be most accurately and expeditiously recorded photographically, while drawings and diagrams may be duplicated for instruction or reference.

In the actual practice of engineering photography has been steadily on the increase for a number of years. In construction work it is now considered necessary to record the 'progress of the work in detail from start to finish, these prints form a record of progress for the offices so that the amount accomplished at any time may be ascertained, and when the work is finished the history of the construction from its inception to its completion is readily available, and forms most valuable information for future work. Such a record is practically impossible by any other method.

It is perhaps interesting to note that photographic surveying has been carried out on a far more extensive scale in Canada than anywhere else. The first work of this kind was done in connection with the route of the Canadian Pacific Railway through the Rocky Mountains, and in 1893 and 1894 the Canadian section of the International Boundary Commission carried out a photographic survey of about 14,000 square miles of territory along the boundary between Canada and Alaska. Since then very large areas in British Columbia have been surveyed by the same method. These surveys, on the authority of the Surveyor-General. can be executed at a fraction of the cost of other methods and with greater precision, so there seems to be no valid reason why the method should not be almost exclusively used where the nature of the country warrants it.

Many other applications of the camera might be enumerated and will no doubt suggest themselves to the reader, but enough has been said to show how wide and varied are the uses to which photography may be put and its great value as an aid to scientific work. Such being the case, it is, we think, of prime importance that every student and practical worker who desires to have such an aid should make himself master of the rudiments of the work.

I shall conclude this paper by giving two simple examples of the application of photography to numerical work which requires no special apparatus.

1. Given the position of any point to determine the distance of another point further away. Let two photographs be taken, including both points, from two stations a known distance apart, the camera having the same bearing in each case.

Let P' be the known point at distance A.

Let P be the required point at distance D.

Let F be equal the focal length of the lens.

Let X and Y be the separation of the points in the resulting photographs.

Let E equal the base line.

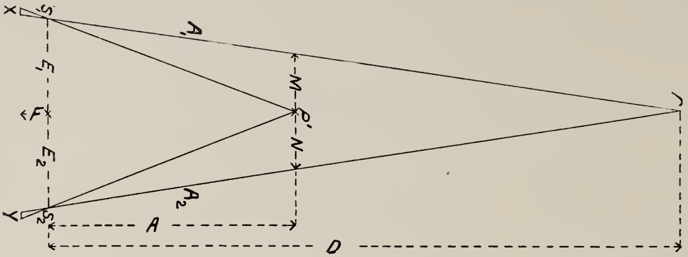


Fig. 1

$$\text{Then } \frac{Y}{N} = \frac{F}{A_2}, \quad \frac{X}{M} = \frac{F}{A_1}$$

$$\therefore \frac{X + Y}{M + N} = \frac{F}{A} \text{ approx.}$$

$$X + Y = \frac{F}{A}(M + N) \quad \ldots\ldots \quad (1)$$

$$\text{Again, } \frac{M}{E_1} = \frac{D - A}{D}, \quad \frac{N}{E_2} = \frac{D - A}{D}$$

$$\therefore \frac{M + N}{E} = \frac{D - A}{D} \quad \ldots\ldots \quad (2)$$

$$\text{From (1)} \quad \frac{X + Y}{E} = \frac{F}{A} \cdot \frac{M + N}{E}$$

$$\text{Subst. in (2)} \quad \frac{X + Y}{E} = \frac{F}{A} \cdot \frac{D - A}{D}$$

$$\text{Or} \quad X + Y = E \cdot \frac{F}{A} \cdot \frac{D - A}{D}$$

$$\therefore D = \frac{A \cdot E \cdot F}{EF - A(X + Y)}$$

The subjoined photographs, taken a couple of years, represent an application of this method to the determination of the distance of the Union Station from College Street, the base line in this case

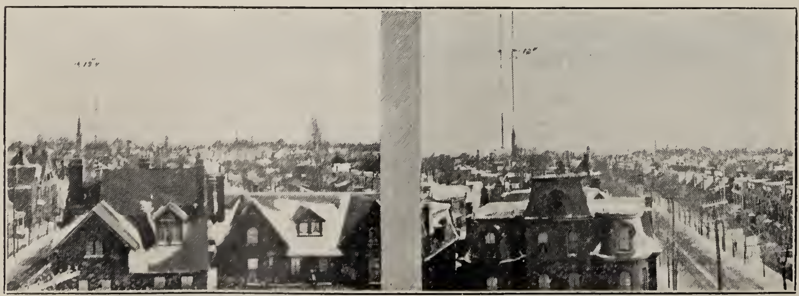


Fig. 2

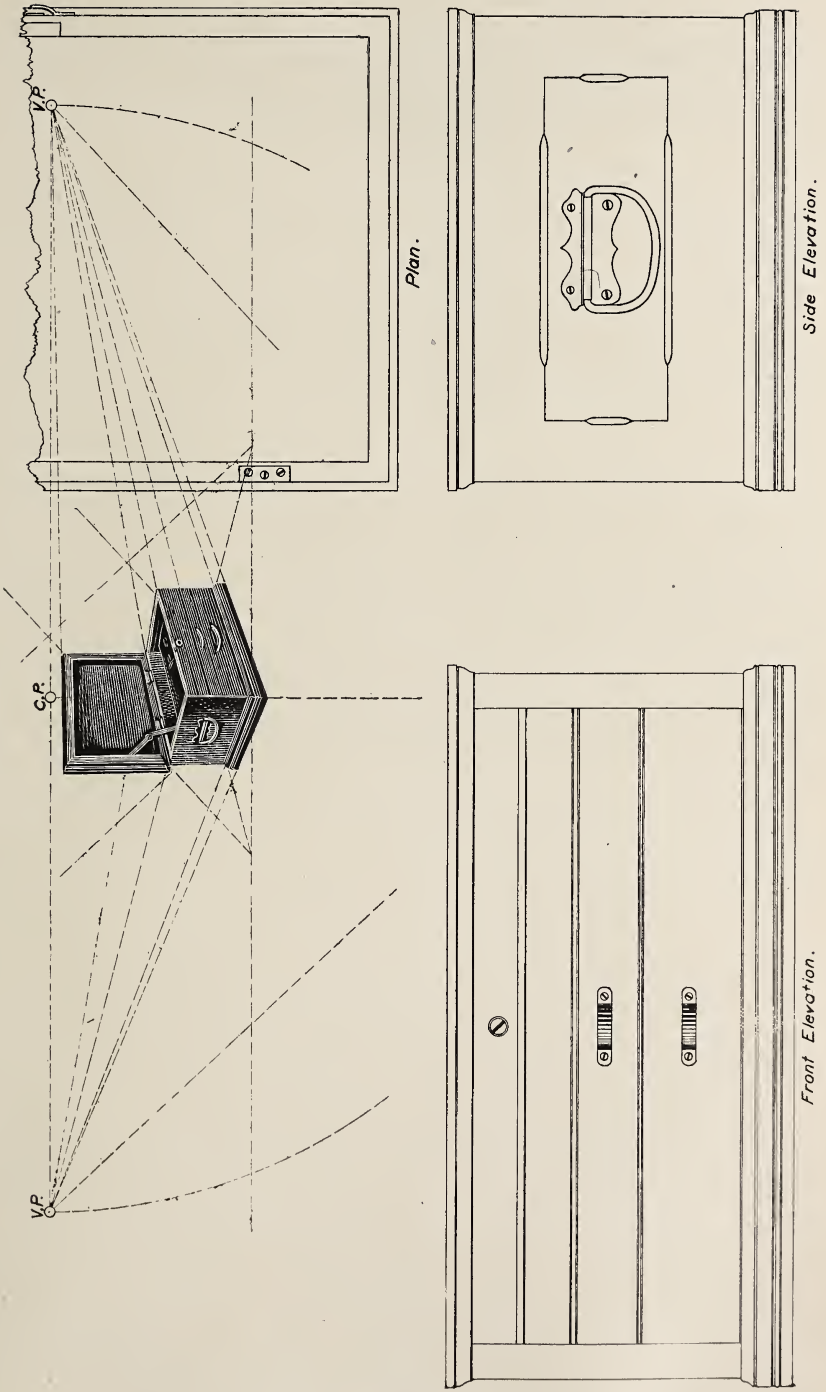


Fig. 3

being 116 feet, the distance A 1,600 feet, and the focal length of the lens 6 inches.

The result calculated from the prints was less than 5 per cent. in error, which may be considered a fair result.

Problem 2.

Given the focal length of the lens and its distance from a vertical line of an object to produce a drawing to scale from the photograph.

Let F equal focal length of lens.

Let D equal distance from optical centre of lens to object.

Let L equal length of any vertical line of object, and l equal the length of this line in the photograph.

Let x equal distance from lens to plate.

$$\frac{1}{D} + \frac{1}{x} = \frac{1}{F} \quad \text{whence } x \text{ is determined}$$

Then $$\frac{l}{x} = \frac{L}{D} \quad \text{whence L is determined}$$

This gives the dimensions of one line of a perspective drawing and from this drawing the elevations of such faces as are visible may be constructed.

The accompanying illustration from a class problem shows the application of the method to the detail drawing of a small tool chest. In this case the error in the result was under 2 per cent., which amount would be decreased if more than one photograph were used.

The accompanying illustration from a class problem shows the application of the method to the detail drawing of a tool chest.

A NEW TYPE OF CRUDE OIL ENGINE AND SOME INDICATOR DIAGRAMS

H. ADDISON JOHNSTON, '00.

The internal combustion engine has developed so rapidly during the past ten years that it is very seldom that small steam engines are met with in commercial operation, except as auxiliaries in large power plants where steam is always available.

The fuel generally used in small internal combustion engines is gasoline, but a small number use city gas, and a very few kerosene. All these fuels are manufactured products, and hence are very expensive. In small units the total cost of power is low because very little fuel is used, but when over 20 h.p. is required the cost of fuel becomes excessive. Moreover, the increased use of gasoline engines is causing such a demand for gasoline that the oil companies have difficulty in obtaining a sufficient supply as the percentage of gasoline in crude petroleum is very low. The price of gasoline has more than doubled in the last few years, and there is no indication that the top price has been reached yet.

The use of crude oil in internal combustion engines has seemed to the writer to be the solution of the cheap power problem, and after about four years of constant experimental work an engine has been developed which will operate perfectly on any grade of crude petroleum or its refined products. Crude petroleum varies in price from less than one cent to about five cents per gallon, according to locality, quality and transportation conditions. The engine developed by the writer will deliver 10 h.p.-hrs. on three-quarters of a gallon of any kind of oil, hence, even at the highest price, the cost of fuel amounts to less than one-half cent per h.p.-hr., and at the lowest, under one-tenth cent per h.p.-hr.

The principal cause of failure of previous attempts to use crude oil in internal combustion engines has been the clogging of the various parts of the mechanism with tar and carbonaceous material from the fuel. This trouble is due to the fact that experimenters have endeavored to vaporize the oil to form explosive mixtures. Crude oil contains a large percentage of heavy hydrocarbons which will not vaporize under the action of heat, but merely break up into lighter hydrocarbons and tar, the latter settling on the nearest support and building up until it interferes with the running of the engine.

It is thus quite evident that for a successful machine, some other method of operation must be devised. It is well known that both tar and carbon will burn under proper conditions, hence the problem is reduced to the providing of such conditions in an intenal combustion motor that the tar and carbon contained in the oil will be instantaneously consumed.

The most favorable conditions for the rapid combustion of any fuel are these: the fuel should be broken up into the smallest possible particles; each particle should be surrounded with air; and the air should be at as high a temperature and pressure as practicable. If it is assumed that ten per cent. of the bulk of the oil will appear as tar under the action of heat, and that the largest particle of oil after breaking it up is one-two hundredth of an inch in diameter, then after the ninety per cent. of oil has burned off there will be left a particle of white hot carbon a little over one-thousandth of an inch in diameter, and surrounded by air at a very high temperature. Under these conditions the carbon burns instantaneously and no fouling of the cylinder walls or passages is possible. It has been assumed that the small particles of oil remain suspended in the air until they are burned. In practice it has been found that if a water-jacketed combustion chamber is used that some of the oil strikes the cold walls and sticks there, the lighter portion burns off and the tar remains, eventually causing clogging. If, however, the cylinder walls are kept at a temperature high enough to shed the oil as water is shed from a hot iron, then there is no tendency for tar to accumulate, and after a long run the cylinder will be found to be burned absolutely clean.

Fig. 1 shows the cylinder construction by which the conditions for rapid and complete combustion are provided.

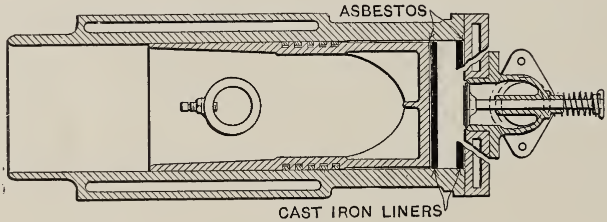


Fig 1

The cylinder and piston are each provided with an extension which is not cooled. The water jacket extends only over that part of the cylinder in which the piston rings run and the piston extension is made one-sixteenth inch smaller in diameter than the bore of the cylinder, and hence does not touch the cylinder walls. On the end of the piston and on the inside of the head there is an asbestos insulated liner which prevents the escape of heat from the combustion chamber.

In operation the cycle is as follows: Air alone is drawn into the cylinder through a mechanically operated inlet valve during the suction stroke; on the return stroke the air is compressed to about 150 pds. per square inch, and just as the crank reaches the centre a charge of crude oil is sprayed into the cylinder by compressed air and is immediately ignited by striking a hot plate on the end of the piston. The fuel burns practically instantaneously and the rise in temperature of the charge causes a corresponding rise in pressure. (At full load the maximum pressure may reach

400 pds. per square inch.) The piston is forced out by the expanding gases and at the end of the stroke the exhaust valve opens, allowing the burnt gas to escape during the succeeding stroke.

To ignite the first charge when the engine is cold a thimble is provided on one side of the cylinder which is heated red hot by a torch, this operation requiring about three minutes. When instantaneous starting is required an electric device is provided which fires the first few charges. After the engine is running no further heating is required as the combustion of the oil keeps the plate on the end of the piston at a temperature above the ignition point.

Compressed air for spraying the fuel and for starting the engines is supplied by a two stage air pump attached to the crank shaft.

In working out the principles of this engine many thousand indicator diagrams have been taken and a few interesting types are shown herewith.

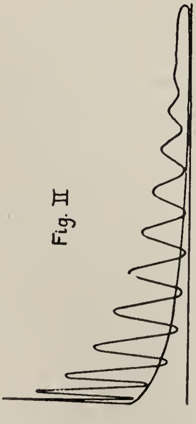
The first two months after the experimental engine was finished were occupied in attempts to make the engine run, and continue to run, on fuel oil, and at the end of the second month we had progressed so far that the engine would continue running if no load were put on it. The M.E.P. of our indicator cards at that time did not average more than 12 or 15 pds. This low figure was gradually improved upon until after four months 45 pds. was reached.

About this time the "explosion wave" began to give evidence of its existence and Fig. II. shows the register of an explosion wave on the indicator card. It will be noticed that extremely violent vibrations were set up in the indicator piston and that the vibration continued almost the entire stroke. The suppression of these explosive waves constituted the most difficult problem in the working out of this type of engine, and it is most fortunate that the laws governing their formation have been discovered. The external evidence of these waves was a terrific pound, which would cause an observer unfamiliar with the case to think that the engine was knocking itself to pieces. In the gas engine pounding is caused only by too early ignition, but that the cause is not too early ignition in this case may be seen by examining Fig. III., in which case the igniation is quite distinctly too late, but the explosion wave is still there.

An average normal diagram is shown at Fig. IV., M.E.P. 95 pds. The highest M.E.P. yet obtained on a normal card is 107 pds. Fig. V. shows very clearly the action of the governor in cutting off the supply of fuel when the load is reduced. Note that the compression pressure remains the same in every case, giving ideal conditions for high efficiency under light load.

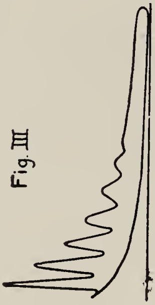
Fig. VI. shows two diagrams taken at different speeds. The increased inertia effect of the indicator drum at high speed stretches the indicator card and makes the diagram longer. Note that while no change has been made in the timing of the fuel valve

Fig. II



Explosion Wave

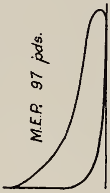
Fig. III



Explosion wave with delayed ignition

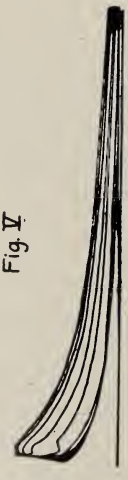
Fig. IV

M.E.P. 97 pds.



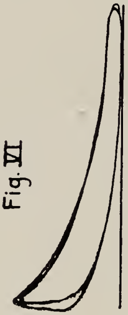
Average normal card

Fig. V



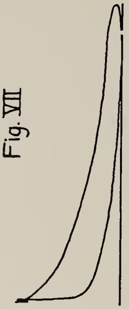
Showing action of governor when load is off

Fig. VI



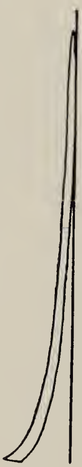
Card taken at fast and slow speeds

Fig. VII



Fuel injected too early

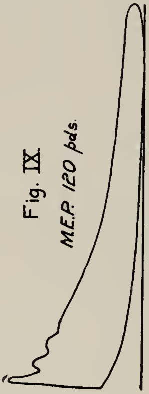
Fig. VIII



No load diagram

Fig. IX

M.E.P. 120 pds.



Freak card

the ignition occurs approximately at the correct time at both speeds.

Fig. VII. shows the effect of injecting the fuel too early in the stroke. The maximum pressure is reached before the piston has completed the compression stroke.

A typical no load diagram is shown at Fig. VIII.

Fig. IX. is a freak. This card was obtained when the engine was being started. The previous charge had not fired, part of it remained in the cylinder, vaporized, and was fired with the succeeding charge just at the right minute.

The 60 h.p. two cylinder vertical engine shown in the cut* is built for direct connection to generator and runs at 300 r.p.m. Its guaranteed fuel consumption is 4½ gallons crude or fuel oil per hour, full load. It is equipped with compressed air starting mechanism, which turns compressed air into each cylinder alternately at the time corresponding to its power stroke. The small two-stage air compressor seen beside the cylinder is driven from the crank shaft and supplies air for starting and for spraying the fuel. The engine may be started at any time in less than five minutes, and when once started needs no further attention. The cranks run in oil and outside bearings are lubricated with ring oilers.

With oil at 4 cents per gallon, 100 h.p.-hrs. from this engine would cost only 30 cents, or $9.00 per horse-power-year on a ten-hour day basis.

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*Note—See page ii, advertising section, for cut of 60 h.p. two-cylinder vertical engine described above.

A COMPARISON OF DIRECT CURRENT AND INDUCTION MOTORS

L. G. IRELAND, '07.

It is the purpose of this article to make a brief comparison of the relative advantages and disadvantages of the polyphase induction motor and the direct current motor, more particularly the shunt motor, since its characteristics most nearly approach those of the induction motor.

The work which motors are called upon to perform may be broadly divided into two classes:

(1) Constant speed operation,
(2) Variable speed operation.

Let us first consider the case of constant speed operation. For constant speed work the squirrel cage type of induction motor is used. In this type the line connections are made to the primary or stationary element and the secondary or rotating element consists of a winding of copper bars permanently short-circuit by rings at each end. The secondary receives its currents by induction from the primary, the alternating currents in which set up a synchronously revolving. It is thus evident that no electrical connections are made to the revolving element, and in this elimination of moving contacts lies one of the greatest advantages of the induction motor. The secondary of an induction motor is also much more simple mechanically than the armature of a direct current motor with its commutator and all its attendant troubles.

Speed regulation is usually defined as the difference between no-load speed and full-load speed, expressed as a per cent. of no-load speed. This quantity, when used in connection with induction motors is termed full-load slip. The performance of the induction motor in regard to speed regulation is, in general, superior to that of the shunt motor. The following figures give values of speed regulation for both types of motors under constant voltage conditions:

Shunt motor - - - - - - - - - 10 to 12% drop.
Induction motor - - - - - - - - 3.5 to 5% slip.

The above figures are merely average values, considerable variation being found in different motors. Very few induction motors, however, have a full-load slip higher than 7%, unless specially designed with high-resistance short-circuiting rings in order to give a very large starting torque.

The induction motor requires no attention while running, whereas if the speed variation of the shunt motor is to be kept within the limits of the induction motor, changes must be made in the field resistance as the load changes, and it is possible, of course, to obtain perfectly constant speed by this means. This latter case is scarcely worth considering, as the attendant would require to spend more time in manipulating a rheostat than in operating his machine.

Variable Speed Operation. For this class of service direct current motor is superior. The speed control of direct current motors is obtained by varying the resistance in either the field or armature circuit. The analagous methods for the induction motor are variation of the primary voltage by means of autotransformers, and the use of a phase-wound secondary with variable external resistance connected to slip rings. A third method has been slightly used, namely, that of varying the number of poles. It involves a complicated and costly construction, besides giving only a very limited number of speeds. We will therefore consider only the first two methods.

For a given load the efficiency of a shunt motor is approximately constant at all speeds obtained by field regulation. On the other hand, the efficiency of the induction motor decreases more rapidly as the speed is reduced by voltage regulation. When running at low speeds under variable load conditions, by armature and rotor resistance regulation respectively, both motors show a lack of stability in regard to speed.

A wide range of speeds can be obtained by field resistance variation in shunt motors while in induction motors the range of speeds is comparatively small, or in other words a much greater flexibility of speed control can be obtained from shunt motors than from induction motors.

Starting. The squirrel cage motor is started in a slightly more simple manner than the direct current motor. The former is started by applying by means of autotransformers a reduced voltage to the primary terminals and connecting directly to the line when the motor has attained nearly normal speed. If the motor has a wound secondary with starting resistance, the primary is first connected to the line, all the resistance being in series with the secondary, and the resistance is gradually cut out as the speed increases, until at normal speed the secondary is short-circuited. This method of starting possesses no advantage over the analagous method used in starting direct current motors as far as simplicity is concerned, but it has the very decided advantage of producing a very large starting torque. It is possible, if the secondary resistance is of proper value, to obtain, at starting, the maximim torque which the motor is capable of exerting. The effect of large starting torque may also be obtained in a lesser degree in squirrel cage motors by using high resistance short-circuiting rings but this involves a sacrifice of full-load efficiency and an increased full-load slip.

The method of starting by means of secondary resistance is preferable to starting by means of reduced voltage. When the latter method is used the motor consumes at starting a very large current of low power factor with resulting bad effect on the generator and line. The former method largely obviates these troubles.

Efficiency. The full-load efficiency of the direct current motor is equal to that of the induction motor in good modern machines. At light and medium loads, however, the efficiency of the induction motor is better than that of the direct current motor. It is clear that this is a very important consideration as very many motors run on light loads a large part of the time.

Power Factor. Induction motors never operate at 100% power factor, but always consume a lagging current. The power factor at full load is usually about 90% and is much lower at light loads. This is due to the large relative magnitude of the magnetizing current at light loads. The presence of wattless currents does not mean much loss of energy but limits the capacity of the line and generators by heating and has a bad effect on generator regulation.

The direct current motor has an advantage in this respect, the power factor being, of course, always unity.

Safety. The induction motor is to a large extent self-protecting. If it is subjected to such a heavy overload that it stalls and if for any reason the circuit breakers fail to open, it possesses sufficient inductance to keep the currents within such limits that the primary winding will not be burnt out unless the overload is continued for some time. When the overload is removed the motor immediately starts. This property is especially valuable, if, as in a case which came under the writer's notice, the motor's ordinary load is 50% overload, and the attendant finds it troublesome to renew the fuses every time it stalls, and solves the difficulty by "fusing" with No. O copper. If a direct current motor were subjected to such treatment it would of course mean a burnt-out armature, with subsequent adjournment to the repair shop.

Electric drive is used in many places where all danger of sparking must be absolutely eliminated, for instance, in the coal-grinding buildings of Portland cement mills. For such work the direct current motor cannot be considered, for no matter how well designed the motor may be, the commutation is liable to give trouble, with consequent danger of explosion and loss of life. For operation under these conditions the squirrel cage induction motor is well suited. The only electrical connections on the motor are the terminal board connections to the line, and these are completely insulated. The autostarter, consisting of a two-throw switch and pair of autotransformers, is completely enclosed and the switch contacts are under oil.

Cost. In the matter of cost the induction motor has an advantage in sizes over 10 h.p. for 60 cycle motors. According to figures furnished by one of the Canadian companies, the saving in initial cost of the 60 cycle induction motor over the direct current shunt motor in sizes between 10 and 100 h.p. amounts to between and 10 and 15%. 25 cycle motors are, of course, more expensive than 60 cycle motors, and for 25 cycle installations the saving is not so great.

From the above brief summary it is evident that it is impossible to state broadly that either type of motor is better than the other. Each has its own merits and drawbacks, and the question as to whether direct or alternating current drive shall be installed in an industrial establishment must be settled by the existing conditions in each case.

THE MEASUREMENT OF POWER FACTOR IN THREE-PHASE CIRCUITS

CHAS. H. HUTTON, '07

The following method has been found quick and accurate for calculating the power factor in three phase circuits such as are usually met in commercial work with induction motors, transformers, etc. It possesses the additional advantage that only two quantities are necessary, watts and either volts or amperes in order to find the power factor and the other unknown quantity.

In the following theory, the endeavor has been to use only elementary relations so that the reader will find nothing not taken up in the lecture room, and at any rate he may turn the results obtained to his practical advantage.

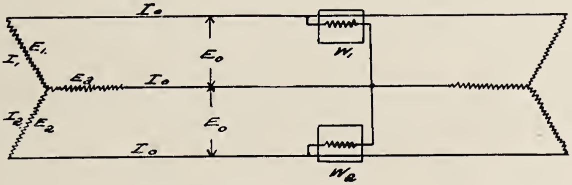


Figure 1.

In any single phase circuit the fundamental relation for power is

$$P = E_0 \, I_0 \cos \alpha \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

where $P =$ power in watts, $E =$ *R.M.S.* volts between lines, $I =$ *R.M.S.* amperes in line, $\alpha =$ angle of space displacement between E and I, $\alpha =$ power factor of the circuit.

To find an expression for the power in a three phase circuit, a circuit may be assumed as represented in Fig. 1. The power in any branch is $P = E \, I \cos \alpha$, hence the power in branch 1 of the star winding Fig. 1 is $P_1 = E_1 \, I_1 \cos \alpha$ and the total power P is the sum of the three individual powers $P_1 + P_2 + P_3$. thus

$$P = E_1 \, I_1 \cos \alpha_1 + E_2 \, I_2 \cos \alpha_2 + E_3 \, I_3 \cos \alpha_3$$

For balanced loads $E_1 = E_2 = E_3$ and $I_1 = I_2 = I_3$ and hence $P = 3 \, E_1 \, I_1 \cos \alpha_1$. Now $I_1 = I_0 =$ current in the line.

$E_1 = \frac{E_0}{\sqrt{3}}$ where $E_0 =$ voltage measured between any two lines, hence

$$P = 3 \frac{E_0}{\sqrt{3}} \, I_0 \cos \alpha_1 = \sqrt{3} \, E_0 \, I_0 \cos \alpha_1 \quad . \; . \; . \quad (1)$$

It is necessary now to prove that the wattmeters as connected in Fig. 1 measure this power P. Since the delta e.m.f. across the pressure coil of a wattmeter is displaced from the star current in the current coil, it is evident that a wattmeter will not measure the power of one individual phase only, but it may be proven as in the following that the algebraic sum of the two indications so mentioned is the true power P as defined above.

Referring to Fig. 2, which shows the relations of current and voltage in the circuit Fig. 1, we have the vector AB representing the current I_1 lagging α° behind E_1 and CA representing the current I_2 lagging α° the same amount behind E_2.

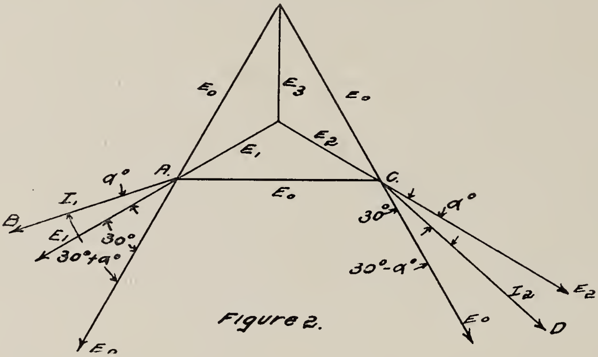


Figure 2.

Then the power measured by wattmeter 1 is $W_1 = E_1 I_1 \sqrt{3} \cos (30^\circ + \alpha)$, and since $E_0 = \sqrt{3} E_1$ and $I_0 = I_1$, $W_1 = E_0 I_0 \cos (30^\circ + \alpha)$.

Similarly $W_2 = E_0 I_0 \cos (30^\circ - \alpha)$ since the angle of phase displacement between E_2 and I_2 is $(30^\circ - \alpha)$.

The algebraic sum of the readings of the two wattmeters is

$$
\begin{aligned}
W_1 + W_2 &= E_0 I_0 [\cos (30^\circ - \alpha) + \cos (30^\circ + \alpha)]. \\
&= E_0 I_0 2 \cos 30^\circ \cos \alpha \\
&= E_0 I_0 2 \frac{\sqrt{3}}{2} \cos \alpha \\
&= \sqrt{3} E_0 I_0 \cos \alpha \\
&= P.
\end{aligned}
$$

Hence the algebraic sum of W_1 and W_2 is equal to the three phase power P.

Further,

$$\frac{W_2}{W_1} = \frac{\cos (30^\circ - \alpha)}{\cos (30^\circ + \alpha)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

It may be proven in a similar manner to the above that

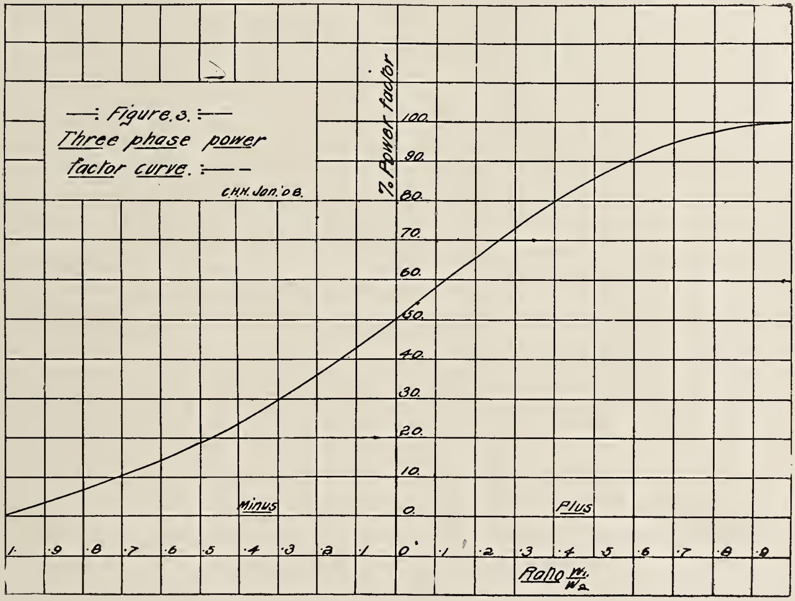
$$W_2 - W_1 = E_0 I_0 \sin \alpha.$$

Hence $$\frac{W_2 - W_1}{W_2 + W_1} = \frac{E_0 I_0 \sin \alpha}{\sqrt{3} E_0 I_0 \cos \alpha} = \frac{\tan \alpha}{\sqrt{3}}.$$

$$\text{Hence } \tan\alpha = \sqrt{3}\,\frac{W_2 - W_1}{W_2 + W_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

From this cos α may be determined since tan α is known. An easier way to find the power factor cos α is to use the curve Fig. 3 which has been plotted from the equation (2) above by substituting valves of α_1 and finding the corresponding relations between W_2 and W_1. Having found the power factor from the ratio of wattmeter readings and the curve, and knowing either volts or amperes the other may be calculated from formula (1).

Some difficulty may arise in knowing when the wattmeter indicates negative power since the pressure coil must be always connected so as to give a positive reading. This may be easily avoided by increasing the load on the circuit, when the wattmeters, if correctly connected, will indicate a corresponding increase in power. When using a polyphase meter, readings of W_1 and W_2 may be obtained by removing the small pressure plugs at the base of the instrument, one side for W_1, other side for W_2.



To illustrate the use of the curve the following examples are given :

$$\text{I.} \quad W_1 = 4600, \quad W_2 = 9000$$

$$\therefore \frac{W_1}{W_2} = \frac{4600}{9000} = .51$$

corresponding to .51 we find the power factor of .867.

$$\text{II.} \quad W_1 = -4600, \quad W_2 = +9000$$

$$\frac{W_1}{W_2} = \frac{-4600}{+9000} = -.51$$

corresponding to $-.51$ we find the power factor of .181.

WATTMETERS AND THREE-PHASE BALANCED LOADS OF VARYING POWER FACTOR

H. W. PRICE, B.A.Sc.

The rate at which energy is transferred through a three-wire, three-phase circuit can be measured by two indicating wattmeters. If the load be 100% power factor and balanced, each wattmeter will indicate half the load, if not of 100% power factor the meters indicate unequal portions of the load.

Not long ago an electrical engineer called on the writer in regard to difficulty with two wattmeters on a switchboard serving a three-phase rotary converter. The board was liberally supplied with instruments, including a power factor meter. The load was balanced, that is the three line currents were equal, also the three between-line voltages. The wattmeters, however, persisted in indicating very unequal shares of the load, in fact, of a total load of 880 kw. one meter indicated 492 kw. and the other 388 kw. The blue-prints showed correct connections of the meters to the lines through shunt and series transformers, and the engineer was certain that actual connections were according to the prints. The meters had twice been checked against standards, and were correct. A question as to power factor was answered by this statement: "The power factor meter shows always about 98%, which for all practical purposes is 100%, and the meters should share the load equally. They must be out of calibration and yet they check against the standards. Something is wrong." A little calculation showed that those conclusions with regard to 98% power factor were not as reliable as the meters, for the variation of 2% from unity power factor accounted for an indication by one meter 25½% in excess of that of the other, or 490 and 390 kw. When the field excitation of the rotary was adjusted to cause 100% power factor, each meter indicated 440 kw.

Consideration of facts and underlying principles in connection with the above forms the subject of this paper.

Fig. 1 shows in diagram a three phase generator connected to a three phase load. Each phase is separate, having two lines of its own. The three generator windings are mechanically located on the armature so that the e.m.fs. 1′, 2′, 3′ attain their maximum instantaneous values in regular sequence, 1′, 2′, 3′, and equally spaced as to time, that is, the three e.m.fs. from the three alternator windings may be suitably represented by three sine waves 120° apart. The wave of e.m.f. from commercial generators is approximately of sine form. These voltages cause currents, 1, 2, 3, also represented by sine waves 120° apart. If the pairs of lines at 4, 5, 6 be replaced by three single conductors, the current in 4, for example, must be the resultant of currents 1′ and 3′ or 1 and 3, hence will also be a sine wave but not in phase with either 1 or 3. Similarly will 5 and 6 carry resultant currents.

In proceeding further it is necessary to adopt a definite method of describing vectors to avoid confusion and mistake. If *p* and *q* be two points *E* volts apart, *p* being higher in potential than *q*, then voltage *E* may be described in magnitude and sense by E_{pq}. The resulting current from *p* to *q* would be called I_{pq}. If it were desired to consider the current as from *q* to *p*, the description would be — I_{pq} or I_{qp}, etc.

In Fig. 2 let it be assumed that currents marked *a'a, b'b, c'c ab, bc, ca,* and voltages marked *ab, bc, ca,* are positive, also that voltages E_{ab}, E_{bc}, E_{ca} pass through their maximum positive values in the order named.

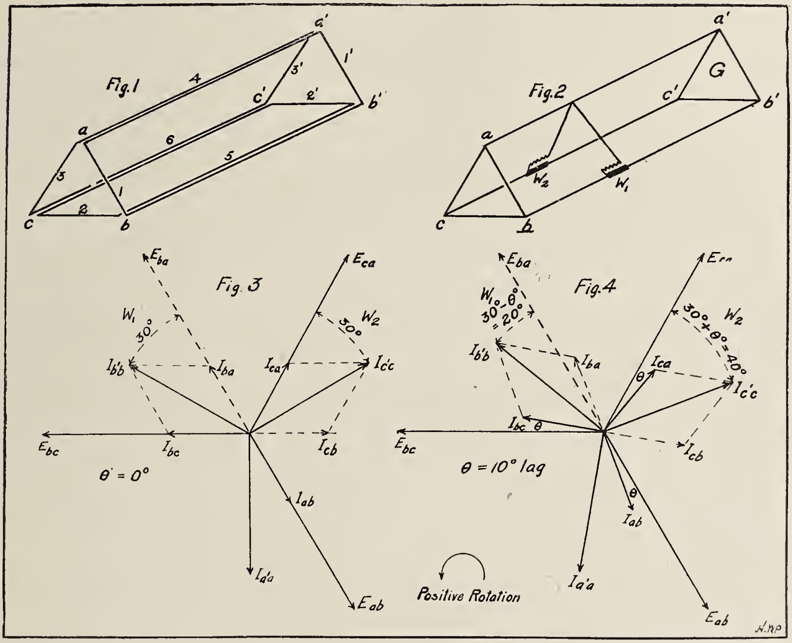


Fig. 2 diagramatically represents the generator and load, and two wattmeters, W_1 and W_2, necessary to measure the load.

In Fig. 3, E_{ab}, E_{bc}, E_{ca}, are represented as equal vectors 120° apart, and will attain maximum positive values in the order named if counter-clockwise rotation be assumed. At 100% power factor these voltages cause equal currents I_{ab}, I_{bc}, I_{ca} in phase with the corresponding voltages. Current $I_{b'b}$ toward point *b* must at all instants be equal to the sum of currents I_{ba} and I_{bc} away from *b*, that is

$$I_{b'b} = I_{ba} + I_{bc} = -I_{ab} + I_{bc}$$

Current I_{ba} is shown dotted and opposite to I_{ab}. Current $I_{b'b}$ is the resultant of I_{ba} and I_{bc}. Similarly may be found currents $I_{a'a}$.

and $I_{c}{}^{1}{}_{c}$. The wattmeter W_1 will indicate because of current $I_{b}{}^{1}{}_{b}$ through its series coil and a small current through its shunt coil in phase with E_{ba} (opposite to E_{ab}) or

$$W_1 = E_{ba}\ I_{b}{}^{1}{}_{b}\ \cos 30^\circ$$

Since $E_{ba} = E_{ca}$ and $I_{b}{}^{1}{}_{b} = I_{c}{}^{1}{}_{c}$ in magnitude, $W_1 = W_2$ at 100% power factor.

Suppose, as represented in fig. 4, the power factor such that the current in each leg of the load must lag θ° behind the voltage causing it. Evidently the wattmeters must alter their indications so that

$$W_1 = E_{ba}\ I_{c}{}^{1}{}_{c}\ \cos\,(30^\circ - \theta^\circ)$$

and

$$W_2 = E_{ca}\ I_{c}{}^{1}{}_{c}\ \cos\,(30^\circ + \theta^\circ)$$

because the change in power factor has caused all current vectors to shift θ° backward with regard to the voltage vectors. In wattmeter W_1 at 100% power factor, current $I_{b}{}^{1}{}_{b}$ through its series coil *leads* by 30° in electrical time-phase the voltage E_{ba} across its shunt winding, while at power factor such that $\theta = 10^\circ$ lag the current $I_{b}{}^{1}{}_{b}$ leads voltage E_{ba} by only 30°—10° or 20°. Wattmeter W_2 at 100% power factor indicates the watt product of voltage E_{ca} and current $I_{c}{}^{1}{}_{c}$ which *lags* 30° behind E_{ca}, while at $\theta = 10^\circ$ lag there is an increased phase displacement of $30^\circ + 10^\circ$ or 40°. Evidently then with lagging currents the indication of W_2 must continue to decrease with increasing values of θ until at $\theta = 60^\circ$ reading W_2 becomes zero since $30^\circ + \theta^\circ = 90^\circ$. Greater lag causes negative indications, to read which the pressure connections of the wattmeter must be reversed. Similarly with leading currents and power factors in the neighborhood of 50%, wattmeter W_1 shows small indications because the lead of $I_{b}{}^{1}{}_{b}$ with regard to E_{ba} is about 90%.

From these facts the following statements are true of balanced loads:—

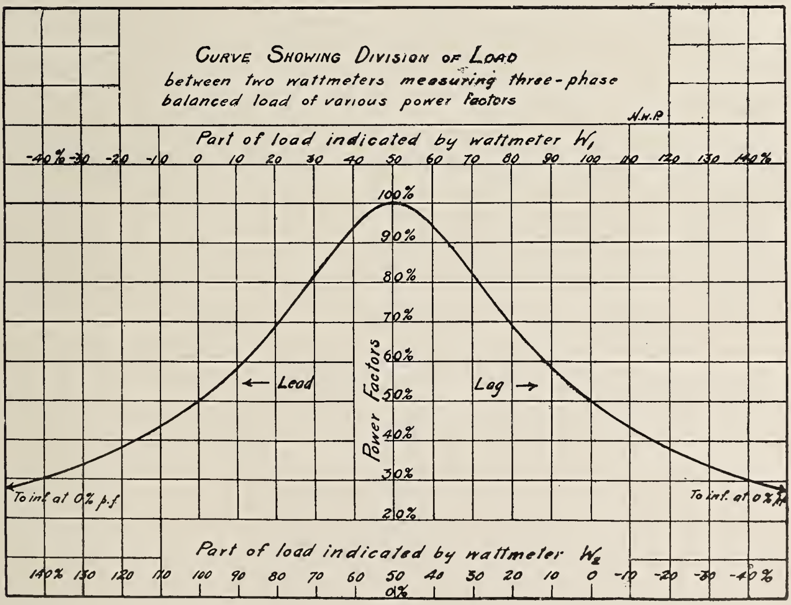
1. With power factor 100%, $W_1 = W_2$, hence each meter indicates one-half of the total load.
2. With lagging currents and power factors between 100% and 50%, W_1 indicates more than W_2, both indications are positive, and $W_1 + W_2 =$ total load.
3. With lagging currents and power factor 50%, $W_2 = 0$ since $\theta = 60^\circ$, hence W_1 indicates the total load.
4. With lagging currents and power factors less than 50%, W_2 becomes negative and W_1 indicates more than the total load. Hence it is necessary to reverse the voltage connections of W_2 to read the meter, and the load is $W_1 — W_2$.
5. With the leading currents, and varying power factor, the same statements apply with W_1 and W_2 interchanged, because the sign of θ is reversed. θ means lag angle of current with regard to voltage causing it. Leading current has therefore a negative lag.

In operating rotary converters or synchronous motors at any load, the power factor of the input currents may be varied at pleasure by adjustment of field excitation. Over-normal excitation causes leading currents, and under-normal excitation lagging currents. The variation in value of the coefficients cos $(30° + \theta°)$ and cos $(30° - \theta°)$ must account for changes in relative values of W_1 and W_2, since any change in power factor or load resulting in altered volt-ampere input causes the same change in $E_{ba} I_{b}^{1}$, as in $E_{ca} I_{c}^{1}$.

Example:— Power factor 95%, $\cos \theta = .95$, $\theta = 18°$, $\cos(30° - 18°) = .978$, $\cos(30° + 18°) = .669$, $\cos 12° + \cos 48° = 1.647$, part of load indicated by $W_1 = \frac{.978}{11.647} \times 100 = 59.5\%$, by $W_2 = \frac{.669}{1.647} \times 100 = 40.5\%$.

In this manner, values for different power factors have been calculated, and results are shown in the curve herewith.

An appreciation of the facts illustrated by the curve will prevent one from making the mistake of a certain road man who, after installing two recording meters on a panel supplying a group of three phase induction motors, observed one meter running "slow," and proceeded to remedy the trouble by "doctoring" that meter till it ran at the same speed as its mate.



AN ELECTRICAL PROBLEM GRAPHICALLY SOLVED

H. W. PRICE, B A.Sc.

Problem.—A question which may be of interest was submitted to the writer a few weeks ago. A manufacturer was using induction motors to operate a large factory, and found the average load to be 200 kilowatts at 60% power factor. To improve the power factor, it was proposed to install a synchronous motor of probably 75 horse-power to be used as a motor and as a "synchronous condenser." Question: "What will the power factor be if that motor is installed?"

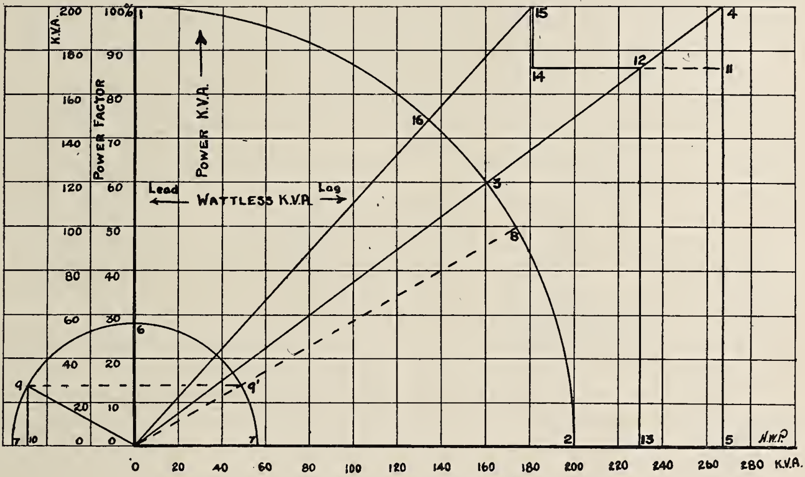
The information being incomplete, it was ascertained further that 200 kilowatts would supply every requirement and induction motors would be removed in so far as the synchronous motor could replace them.

Solution.—See figure. On a sheet of section paper choose point 0. From it draw vertically a line 100 parts long, and describe the quadrant 1, 2. The quadrant will serve very conveniently for reading power factors when supplemented by a vertical scale of power factor as indicated. The direction 0, 1 will serve to represent power input to the plant on a scale as marked, while direction 0, 2 may represent wattless input due to power factors less than 100%.

The power input is 200 k.w. at 60% power factor. To find the power and wattless components of the load, locate the 60% line which intersects the quadrant at 3. From 0 draw 0, 3 produced to intersect the 200 k.w. line at 4. Then 0, 4 represents the k.v.a. (kilovolt-ampere) input to the induction motors, of which the energy component is 5, 4=200 k.w. and the wattless component is 0, 5=267 k.v.a. The synchronous motor is desired to reduce the objectionably large wattless lagging component by neutralizing it so far as possible by wattless leading component.

The rated capacity of the proposed motor is 75 h.p. or 55 k.w. From 0 at radius 0, 6=56 k.w. draw the semicircle 7, 6, 7, which is the locus of the rated k.v.a. capacity of the motor. If the motor were operated at 100% power factor, it would be capable of delivering 56 k.w. continuously without overheating. If its field were over-excited so as to cause the receipt of leading currents, the load would of necessity be reduced to avoid overheating so that the input k.v.a. could not exceed 56 k.v.a. Since the reason for the change in machines is necessity for wattless leading currents to neutralize lagging currents, it is desirable to operate the synchronous motor at fairly low power factor, say 50%. This value permits the motor to deliver one half its rated output and also take leading currents to the extent of 87% of its rated current capacity. The 50% power factor line locates point 8, hence points 9′ and 9 on the capacity circle of the motor. Then with over excited field 0, 9 is the k.v.a. input to the motor, of which 10, 9 is the power input and 0, 10 the wattless k.v.a. input due to leading currents caused by the suitably over-excited field.

The induction motor load 5, 4=200 k.w. may now be reduced by 4, 11=9, 10=28 k.w. to be carried by the synchronous motor, that is 28 k.w. or 37½ h.p. of induction motors may be removed. Since these motors operate at 60% power factor, their removal reduces the wattless k.v.a. input by 11, 12, leaving 13, 12=172 k.w. load for induction motors at 60% power factor. The wattless lagging input 0, 13 of these motors will be reduced by the wattless leading input 0, 10=12, 14 to the synchronous motor, and the latter will deliver power to the extent 14, 15=10, 9.



Hence the new motor, if operated at full load current at 50% power factor with over-excited field, will reduce the total k.v.a. input from 0, 4 to 0, 15 for the same load, 200 k.w., and raise the power factor as shown by intersection at point 16, to 74%

PRACTICAL APPLICATIONS OF THE GYROSCOPE

T. R. LOUDON, B.A.Sc., '05.

It is not proposed in this limited space to deal mathematically with the action of the gyroscope. Although it is almost impossible to explain the curious properties of this instrument in any other than a deeply involved mathematical manner, a few hard and fast statements may be made as to what actually does and will happen under certain conditions, irrespective of the reason for such.

Fig. 1 shows diagramatically the construction of a simple gyroscope. The fly wheel A is mounted in such a manner that it revolves in a plane perpendicular to the frame *E*. If now, the fly wheel be made to rotate at a comparatively high rate (by means of a string wound on the axle) and the frame *E* be held firmly in one's hands, the whole contrivance, simple and harmless looking in the extreme, seems to have become imbued with life. It will be noticed that if the apparatus be moved about in such a manner as to keep the fly wheel always revolving in a plane parallel to its initial plane of rotation, that no activity is manifested, but let the observer try to change the plane of rotation and, instantly, there will be felt a resisting force whose magnitude depends upon the mass of the fly wheel and the rate of revolution. Briefly, it may be said that a body in rotation resists all attempts to disturb its plane of rotation to any other plane than that parallel to the initial plane.

As a first experiment, let a piece of stout cord be tied to the frame of the gyroscope at one end of the axis of rotation (*B* or *C*, Fig. 1) and the string be whirled so that the instrument describes a circle; under the influence of centrifugal force, the whole mechanism tends to rise to such a position at the end of the taut string that the fly wheel revolves in a plane parallel to the plane of the circle described. Another interesting experiment is illustrated at Fig. 2. *A* is an upright steel bar sharpened to a point at one end, the other end being firmly set into a weighted base *B*. The fly wheel of the gyroscope is set in rotation and the small conical seated hole *F* in Fig. 1 is then placed over the pointed upright *A*, Fig. 2. Apparently, in direct opposition to the laws of gravity, instead of falling down, the instrument becomes, as it were, self supporting, balancing on the pivot *A*, Fig. 2, at the same time slowly revolving about on axis through the vertical upright *A*. This last experiment is simply the case of the ordinary top which maintains its equilibrium as long as it revolves with sufficient rapidity.

As a result of its tendency to keep its initial plane of rotation, the gyroscope may be used to show or make evident the diurnal rotation of the earth on its axis. It will, perhaps, be easier to see how this is if one imagines oneself situated exactly at either of the earth's poles. In Fig. 3, *A B* represents the fly wheel of the instrument placed so that its plane of rotation contains the axis of the earth, *P* being say the north pole. The direction of the earth's rotation is indicated by the arrow heads on the full line circle. The gyroscope is set in action and as the earth rotates, the instrument keeping its initial plane of rotation, is, as it were, left behind with the apparent result, as far as the observer is concerned, that the gyroscope seems to revolve slowly about a vertical axis (provision being made for such in the mounting) in a direction counter to what is now known to be the sense of the earth's rotation. This is indicated by the arrow head on the dotted circle.

Gyrostatic action has been made use of to give a horizontal surface for navigator's observations. The first instrument of this kind was merely a top with a polished plane surface at its upper end. The top was set in motion and, of course, came to the vertical, thereby furnishing by its top surface a good horizontal plane. Schlick quite recently invented a gyroscopic instrument in which the fly wheel is run automatically by means of a small air turbine fed from a compressor. This contrivance maintains a horizontal plane surface for any length of time, the air being compressed by a hand pump.

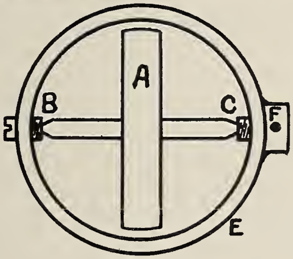


Fig. 1.

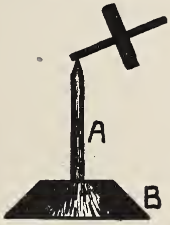


Fig. 2.

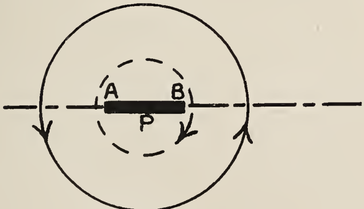


Fig. 3.

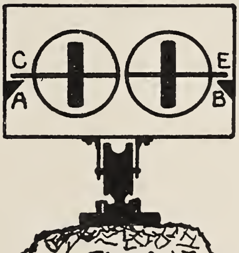


Fig. 4

The so-called "bursting" of fly wheels is generally and quite reasonably attributed to improper design of the material which has to resist centrifugal force. There have, however, been numerous cases in which fly wheels have ruptured and in which the fractured sections were afterwards shown to be both of sufficient area and of flawless material. It is, therefore, quite evident that there must have been some force at work other than mere centrifugal action.

If one considers the usual methods of mounting fly wheels, the revolutions at which they are run, and their massive construction, it is at once seen that these wheels when running are subject to the laws that govern gyroscopic action. Suppose the shaft bearings to wear or work loose from improper supervision, it will not be long before a very serious movement of the shaft takes place as it rotates. Going back to the simple gyroscope, it was seen that if one tries to disturb the plane of rotation to some plane other than parallel to the initial plane, the disturbing force is at once resisted. This is exactly what happens when the plane of rotation of the fly wheel is disturbed by the movement or jumping of the shaft in its bearings—the disturbing force being resisted with the result that undue stresses are brought into action in the spokes and rim. Experiments with flexible rims show the action of these forces very plainly, the wheel being very much distorted when its plane of rotation is disturbed. Of course, the actual case cannot be compared to this, but in high speed engines, it is easy to imagine the effect of the shaft jumping about and causing reversals of the deforming stresses, causing, in fact, tension then compression and so on till weakening takes place and finally rupture from the combined centrifugal and gyrostatic forces.

It will be remembered that a few years ago when the torpedo destroyer ''Viper'' of the British Navy foundered after breaking in half, that the accident was attributed to the gyrostatic action of the high speed steam turbines. Although this theory is now discredited, it is still undisputed that the presence of a turbine with its rotor revolving at a high rate does give rise to serious straining stresses as the vessel pitches and tosses in a sea; that is, as the plane of rotation of the turbine is disturbed.

Passing from what might be termed these theoretical considerations to the practical side of the gyroscope, perhaps the most wonderful and certainly the most useful development is the recent Mono-rail car invented by Mr. Louis Brennan, the inventor of the famous torpedo which bears his name, the main point of which is a gyroscopic steering gear.

This mono-rail car, as its name implies, runs on a single rail; not only this, but it will run on a single cable suspended in mid air, around curves which no ordinary locomotive, double or mono-rail, could ever attempt to round, up grades phenomenal, in fact, anywhere a single rail or cable can be laid or stretched by practical means. Stripped of its historical development, the construction of the invention is as follows: The body of the car may be such as is ordinarily employed, except that on the trucks only one double flanged wheel per axle is used. Somewhere in the body of the car is placed what is nothing more or less than a gyroscope designed to fulfil certain requirements, and it is this apparatus that holds the car upright on its single rail.

Before going into the construction of the steadying apparatus, it is perhaps better to consider what forces have to be overcome by the gyroscope. There is first the very self evident necessity of balancing the car in an upright position on the single rail. Secondly, there is the centrifugal force acting on the whole car when rounding a curve; and lastly, the tendency of the gyroscope itself, considered apart from the car, to turn over when acted upon by centrifugal force. To keep the car upright is a comparatively simple problem, all that is required being a single gyroscope mounted so that the fly wheel rotates in the central longitudinal plane of the car. As long as rotation is kept up, and provided the fly wheel is sufficiently massive, the car cannot overbalance on it single line of wheels. It is, in fact, very much like a large top only that instead of resting on a single point, it has four points of contact. Taking next, the last of the three forces to be counteracted, namely, the tendency of the gyroscope to turn over when under the influence of centrifugal force; it was pointed out that if a gyroscope be attached axially to a string and swung in a circle, that it tended to rise under the action of centrifugal force, into such a position that the fly wheel would rotate in the plane of the circle described. When the gyro-car comes to a curve, the case is analogous to the gyroscope tied to the piece of string and whirled in a circle. Centrifugal force acts on the balancing apparatus of the car with the result that the gyroscope will tend to turn over into such a position that the plane of rotation is parallel to that of the circle or curve described, resulting in the car being toppled over. To get over this difficulty, two gyroscopic fly wheels are mounted side by side in the car and are given rotations in opposite senses with the result that when acted on by centrifugal force, each gyroscope tends to turn over but since their fly wheels are of equal mass and have rotations in opposite directions, they counteract one another thus, as far as the revolving fly wheels is concerned, the car would continue on its journey; but there is still another obstacle to be overcome. The whole car itself tends to upset when rounding a curve just as it would on any double track railway were the outer rail not elevated. This is obviated by having the axles of the fly wheels project beyond their bearings as shown at *C* and *E*, Fig. 4, and placing on the car frame two blocks *A* and *B*. Now, when the car tends to turn over, either the block *A* or *B* comes in contact with the end of the axle *C* or *E*. The whole gyroscopic apparatus then tends to rise up like a top on the axle *C* or *E* depending on which way the car tips, thus pressing on *A* or *B* respectively, in fact, resisting the disturbing force. The result is that the car leans inward as it goes around the curve. Of course, Fig. 4 is a mere diagram as the actual construction has not yet been made public, having no doubt embodied in it many very fine points as obstacles not evident at first sight but which would have to be overcome in the practical case. One very curious thing is the effect of a load placed on the side of the car. Instead of dropping down to the side loaded, the car rises up on that side, this being due, of course, to the gyroscopes resisting the disturbing force.

The great point in favor of such a car is the entire elimination of friction when rounding curves. In a test made on the experimental gyro-car, five feet nine inches long by one foot six inches wide, curves were run over such that the front truck had arrived on the tangent before the back wheels struck the curve. In fact, the only limitation seems to be the distance between the single wheels on each truck. The gyroscopes in this case were run at a revolution of about 7,000 per minute and constituted merely five per cent. of the total weight of the car. The inventor claims, however, that in the practical case, a rate of only 3,000 R. P. M. need be kept up and that balance may be maintained at 850 R. P. M.

"What happens if the gyroscopes stop?" is the natural question of the practical man. The fly wheels are so beautifully mounted in a vacuum that should their driving power be disabled, they still continue to revolve for forty-eight hours and will maintain the car in an upright position for twelve hours. Even at this the doubter objects that the fly wheels themselves may be disabled and to this there is no answer except that, so far, locomotion has not been freed entirely from its dangers no matter what form it takes and certainly the gyro-car is not claimed to be perfection in this direction.

Naturally, the question arises, if a car may be maintained upright on land, why not keep a boat vertical by the same means? This problem has been experimentd with and has proven quite successful. The frame of a large gyroscope was mounted on horizontal pivots so that it could swing fore and aft as the vessel rose and fell to the sea. The fly wheel was then placed in the frame with its axis vertical so that its plane of rotation being horizontal, the vessel could not roll, which, no doubt, would be a relief to passengers.

It may be pointed out in closing that because of the high rate of revolution necessary in order to get good results with a gyroscope, the frame must be of very solid construction so as to hold the bearings firmly. It can readily be pictured what havoc a fly wheel running at a rate of 7,000 revolutions per minute would create by getting loose from its bearings.

IRON RANGES OF THE NIPIGON REGION

A. P. COLEMAN, M.A., Ph.D.

Almost all the areas mapped as Huronian in Northern Ontario contain more or less of the iron formation, though up to the present only three of these areas can be said to have furnished iron mines, Michipicoten, Atikokan and Moose Mountain. The Helen mine is the only one working on a large scale. Naturally the iron ranges of the other regions have attracted much attention from prospectors and geologists, so that most of them have been more or less carefully explored and mapped, without, however, disclosing up to the present any large ore bodies.

There are several iron ranges on, or near, the shores of lake Nipigon on which exploration work has been done, especially two on the east and north-east of the lake, the Poplar Lodge and the Red Paint River ranges. On the former a good deal of stripping and diamond drilling have been done, mainly by the Lake Superior Corporation, under the general direction of Prof. Willmott, and by an unknown company represented by Mr. Flaherty.

During the past two summers the geology of these two ranges has been worked out by myself, with the assistance of Mr. S. E. Moore, and Mr. Green, for the Bureau of Mines of Ontario; and it is proposed to give a sketch of the relationships in this paper.

The Poplar Lodge iron ranges are three in number, near the east shore of Lake Nipigon, northern, central and southern, but as one goes inland they seem to come together so as to form only one range, running somewhat north of east and ending about twenty-five miles from the shore. The three bands of iron formation near Poplar Lodge, an old Hudson Bay post, are the parts which have attracted most attention, though claims have been taken up as far north-east as the range is known to run.

Owing to widespread old lake deposits of sand and gravel, and equally widespread swamps and muskegs, the solid rocks of the region are concealed over more than half the surface; but in general they have been found to consist of green and gray schists with the banded silica and iron ore of the iron formation, belonging to the Keewatin, the lowest known geological formation, and conglomerates, representing the Lower Huronian. Through these schistose rocks, now generally titled nearly on edge by mountain folding, various eruptives have come up, especially great masses of diabase supposed to belong to the Keweenawan age. The three bands of iron formation run parallel to the schistose structure of the Keewatin and Huronian, and, no doubt, represent the top of the Keewatin.

It is rather curious that the three bands, which run parallel to one another, only a mile or two apart, have very different characters. The northern range, which is not very wide, runs along the north side of Sturgeon River against a range of greenstone hills, and consists of quartzitic looking silica with magnetite and also a little hematite. The range is too narrow and lean, so far as known, to have any economic value.

The central range lies in low land and is much covered with drift deposits and peat, but has been shown to be about a third of a mile broad and two or three miles long. In this range there is no magnetite, so that the compass is not at all disturbed, the whole of the iron existing as hematite, red or black and lustrous, in bands alternating with red jasper and other varieties of silica. The formation is most attractive in appearance, and has been crumpled in the most elaborate way. Unfortunately the bands of ore are never very wide, seldom more than an inch or two, though the hematite itself is of excellent quality. Considerable parts of the formation might run 35 per cent. of iron, silica being the other ingredient; but no important tonnage of higher grade ore can be seen on the surface or has been demonstrated by drilling. If there are ore bodies of high grade and good size they have not yet been uncovered.

The southern range is magnetic, like the northern range, and being of harder materials than the central range, is more apt to rise as ridges. Here the magnetite is banded with quartzitic silica in some places, but often lies between thin bands of slate. There is a little red jasper and hematite present also; and the range is in some places two or three hundred feet wide. Parts of the magnetite are high enough in iron to make a marketable ore, but whether large deposits exist has not been demonstrated. The inland extension of these ranges, along Wendigokan Lake and farther to the north-east, is of a mixed character, containing both magnetite and hematite; but does not differ very greatly from the ranges just described.

The other iron range geologically mapped lies some distance inland from the north-eastern end of Lake Nipigon, near the head waters of Red Paint River. The projected line of the new Transcontinental Railway runs close to several of the outcrops, so that in a few years access will be easy. At present the region can be reached most readily by canoe on the small and winding Red Paint River. Some stripping and drilling is being done under the direction of Mr. Flaherty, who was enterprising enough to take in all the parts of a diamond drill in a large Peterboro' canoe.

The iron formation near the watershed between Lake Nepigon and Hudson Bay consists partly of jasper and hematite and partly of gray quartzitic looking silica with magnetite, the whole enclosed in green or gray schistose rocks or greenstones of the Keewatin. The beds are, as usual, nearly vertical in attitude, and in some places the band is more than 100 yards wide, but with a good deal of schist interbedded with the ore and silica. Here, as in the Poplar Lodge region, there are long stretches of iron formation, but up to the present no deposits rich enough to be classed as marketable ore have been found.

In the American iron ranges of Keewatin age it has been the usual experience that the iron formation occurs in synclinal bands, but that ore bodies are found only under special conditions, where a basin has been cut off by dikes or in some other way affording a cavity in which iron compounds, leached by descending waters from the lean iron range above could accumulate. The ore bodies then are of secondary origin, magnetite, or hematite, or siderite, being dissolved from the banded silica or other iron range rocks and redeposited in the basin, generally as hematite or limonite.

In Ontario we have an instance of the same kind in the Helen Mine, at Michipicoten, where a mixture of brown and red hematite has been deposited in a basin at the bottom of a narrow syncline, the materials being derived from banded iron ore and silica, siderite and also pyrites.

The other two important known bodies of iron ore in Ontario, the Atikokan and Hutton township deposits, are, however, of a very different type. They are parts of the iron range itself, rich enough in iron to be used as ores. They contain much less than usual of the interbanded silica, which is often replaced by a green hornblende rich in iron. They represent then locally enriched portions of the regular iron formation and not separate concentrations in basins beneath the leaner rock above.

In regard to the ranges east of lake Nipigon some parts of the southern range near Poplar Lodge come near to being a low grade ore, but most other parts of the iron formation are far too lean to be used as ores.

In this region the best hope of ore lies in exploration of the low ground, covered with drift or swamp, where deposits of secondary hematite or limonite may lie concealed.

It has proved very disappointing that such extensive development of the iron formation as one finds in Northern Ontario have so far furnished only three important bodies of ore, in contrast with the many great mines south and west of Lake Superior in Michigan, Wisconsin and Minnesota, from a smaller extent of the formation.

Why our iron ranges should be so much poorer is hard to understand, unless President Van Hise's theory is correct that our region has been more powerfully scoured by the ice sheets of the glacial period, removing and mixing up with other glacial debris the ore bodies that once existed.

It may be, however, that the work of exploration has been too superficial up to the present, and that important ore bodies have been overlooked because buried under peat bogs or old lake deposits. Secondary ore bodies consisting generally of hematite or limonite have no effect on the dip needle, the instrument generally used to trace the iron formation when concealed in these ways. It shall be remembered that this method only proves the existence of magnetite such as occurs interbanded with silica in the iron ranges and gives no hint of secondary iron ore bodies not containing magnetite.

It may require a large expenditure on stripping, test-pitting and diamond drilling to finally settle the problem of iron ore distribution on the ranges of Northern Ontario.

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Editorial

Will the Men of 1910 be "Slated"?

"There is a very strong feeling current in our first year that the men of 1910 will be slated at their examinations in consequence of the lack of accommodation." The above is quoted from a contributed article in the last number of "Applied Science." There is no doubt that the article accurately stated the condition of affairs from the standpoint of the undergraduate. There is also no doubt that the Faculty of Applied Science is shamefully overcrowded, that the classes are too large, that the laboratories are congested, that the student does not feel that he is in direct touch with the lecturer and that he is losing heavily in consequence.

Nevertheless it is equally true that no one will be "slated" because of lack of accommodation higher up, since the spout is no more congested than the hopper.

But yet the fact remains that last year 35 per cent. of the men failed to pass the required examination, while over 50 per cent. of the remainder carried stars with them into their second year; only 65 in a class of 248 were able to attain the comparatively low honor standing required in the Faculty, and in many quarters a fixed opinion prevails that a certain percentage of the men must of necessity be plucked every year.

Why do so Many Freshmen Fail?

The question naturally arises, why this distinctly unfavorable showing? Is it the fault of the men, the curriculum or the teaching? Obviously something is seriously wrong. No one will argue that the class of students at the "school" are mentally inferior to those in the other faculties. All will admit that the teaching staff are doing remarkably good work, considering the circumstances. Our graduates go out into the world and hold their own in competition with those of other engineering colleges. Why, then, this slaughter of the innocents in their first year? The process of elimination has brought us to the curriculum. Is too much ground covered in the first year for the average student, with junior matriculation standing to thoroughly, or even satisfactorily, master the details?

The examination results seem to indicate there is. This view seems to be thoroughly established by the fact that in six years only two men of senior matriculation standing, or better, failed to pass the required examination, and practically all took honors.

Should the Standard of Entrance be Raised?

The ideal preparation for an engineering education is a literary and scientific course of a general nature, extending over three or four years. Living up to this ideal is impossible to the average student. Practically all authorities, however, agree that a thorough grounding in mathematics is absolutely essential. Doubtless there would be fewer failures if more personal attention were given to the men; that is, if secondary school methods were introduced. But the true reason seems to be the lack of proper preparation, not of accommodation. A large percentage of the students entering the school are too young, their minds are immature and insufficiently developed to deal with the interpretation of the abstract quantities constantly encountered in the first year. In a number of cases they have been rushed through their high school courses and have carried away with them an undigested mass of unrelated facts, producing in many cases what might be called mental dyspepsia. Their memories have been developed at the expense of their reasoning faculties, in short they have not been trained to think.

This applies pre-eminently to mathematics. Unless the student has been very diligent his mind retains nothing beyond a chaos of formulae, hard to remember, and a few mechanical means of solving abstract questions; he is incapable of applying an equation to a practical problem; a formula has practically no meaning to him.

Why is the Present Matriculation Standard too Low?

That a man cannot be too well grounded in English may be accepted as axiomatic in all branches of education; that he cannot be too well grounded in mathematics is equally true in technical education. Economy of time is the only limitation. There has been a demand for years that lectures in English be added to our curriculum, but as it is already overloaded such a move has been deemed impracticable, until the course is lengthened by another year. As a result the graduates are seriously handicapped in their career.

Contracts, tenders, specifications, reports, are essential features of an engineer's business. He should have the ability to express himself concisely and accurately, second only to a lawyer. The present standard certainly does not give the matriculant this ability. However, apart from their culture values, the lack of languages will not hamper the student during his technical course. The essential feature is a thorough grounding in mathematics. Does the junior matriculation give this grounding? Most certainly not, since trigonometry, higher algebra, including progressions, variations, maxima and minima, and advanced geometry are not even touched. Nevertheless trigonometry is used in almost the first lecture in statics, and variation in dynamics. The result is the lectures, instead of being lectures in statics and dynamics, become lectures in mathematics. Time is lost by the lecturer; he cannot take time to drill on the mathematics, consequently when he proceeds into statical or dynamical aspects of the subject, a large percentage of his class are thinking of the mathematical side. They constantly fall behind and sink into the slough of despond.

Dean Galbraith in a paper read before the American Association for the Advancement of Science in 1897 said: "The student cannot afford the time involved in deferring the study of dynamics until he has acquired a working knowledge of calculus (now a second year subject). As a consequence he becomes confused regarding the origin of his difficulty, and possibly attributes to his ignorance of mathematics, misconceptions, the nature of which may be purely dynamical." It is about this time that the student becomes dissatisfied with his course and goes around lamenting, it is too theoretical; not practical enough.

Admitting that this putting the cart before the horse is not incongruous; that teaching mathematics sporadically, as required, is good educational principle, and the lost time, taken by a lecturer to teach another man's subject, is fair to the lecturer; does the teaching of mathematics as at present conducted give the student a good grounding in all necessary branches of the subject? Would not the time be better employed by raising the standard to an equivalent of the present senior matriculation and requiring the student to stay one year longer in the high schools? In other words, which will produce the better results, ten months' work in small classes, under strict supervision, or six months, in large classes, a few lectures a week, under no supervision whatever? Theoretically the present system should give a good foundation. Under ideal conditions with ideal students it would. But, unfortunately, we have to deal with neither. The average freshman newly freed from restraint will not work at full pressure from beginning. Hence, the disastrous results are shown by examination returns. It is true that by dint of cramming he may make the grade, only to suffer in his future work. It is the opinion of some of our most conservative professors that 33 to 50 per cent. of the senior year could not pass fair papers in first and second year mathematics.

How do Successful Engineers Regard Mathematics?

Mathematics is the foundation of a technical education; it is to an engineer what anatomy is to a surgeon, what chemistry is to an apothecary, what drill is to a soldier. We are pleased to call this "The Faculty of Applied Science." Is not a great portion of the first year spent in pure mathematics to the detriment of applied mathematics?

Mr. Ralph Modjeska, a prominent American engineer of foreign birth and training, in a paper read before the American Society for the Advancement of Science, referring to the teaching in mathematics argued along the following lines: The method of presentation should be such that the student knows the why and the wherefore of each operation, in other words that he learns to think mathematically. One does not know a foreign language unless he can think in that language. One does not know mathematics unless he can think mathematically. It is not necessary for this to go up in higher mathematics, but it is necessary to be thoroughly drilled in the elementary principles of this subject. These elementary principles should become a second nature to the student just as language becomes a second nature when it is thoroughly acquired.

Problems arise every day in the practice of an engineer which a mathematical mind can solve without going into calculations, the principles of maxima and minima those of least work and others are invaluable in assisting at a logical solution of many problems without the use of paper and pencil; but, in order that they may be applied one has to be able to think mathematically.

When Should the Change be Made?

An agitation is being carried on in all of the faculties which has for its object the raising the standard of entrance to senior matriculation. In Arts the endeavor is to shorten the University course. In Medicine the object appears to be to still further close the profession. In Applied Science we need the change because the average student suffers throughout his course under present conditions.

Are we dealing honestly with the parents of the province, who furnish the money to send their sons to college? We accept the applicants and then calmly slaughter the freshmen at their examinations. Should not the case of the "school" be considered separately and immediately?

The Department of Applied Mechanics announces that it is desirous of forming a collection of photographs and drawings of bridges and buildings, completed or under construction, which exhibit features of interest from an engineering point of view. While the illustration of current practice is of chief importance, it is hoped that the older structures, showing the methods of construction in vogue many years ago, and which are of interest in a study of the evolution of design, will be represented. Graduates and others interested who desire to help in the work are requested to send in any photographs or drawings which they think would be of interest.

WHAT WE ARE DOING

Our readers will be interested to learn of the election by acclamation of our esteemed Dean, Dr. Galbraith, to the presidency of the Canadian Society of Civil Engineers for the year 1908. The privilege of presiding over the deliberations of this Society, representing as it does the engineering profession in Canada, and including in all classes some seventeen hundred members, is one that carries with it no little distinction, and Dean Galbraith's many friends are exceedingly well pleased that the honor is to be his for the ensuing year Dean Galbraith has been a member of the Canadian Society ever since its charter was granted in 1887, and since 1894 has served almost constantly on its Board of Councillors.

The meetings of the Engineering Society have been uniformly successful. The last general meeting might have been termed a concrete meeting. Two gentlemen representing two entirely different systems were present, and an impromptu debate livened interest in the subject under discussion.

Such a lively interest is being manifested by the undergraduates in the sectional meetings that special sessions have to be arranged to accommodate those who are willing to contribute papers. This is a pleasant change to the old order, when the president had to plead for addresses and discussions.

The fourth year are all working hard to complete their theses. The following is a list of men in the electrical and mechanical department, together with the subjects they have chosen for investigation:

F. G. Allen—The Electric Lamp.
H. D. Bowman—Electric Power Distribution in Machine Shops.
W. S. Brady—Electric Illumination.
C. G. Carmichael—The Standardizing Laboratory.
S. D. Evans—High Tension Transmission.
F. R. Ewart—Switchboards and Their Apparatus.
C. S. Grassett—Electric Power Transmission.
H. O. Hill—Producer Gas for Power.
T. H. Hogg—Design and Construction of Ontario Power Company's Plant.
C. W. Hookway—Electrical Illumination.
A. H. Hull—Factory Testing of Generators and Motors.
C. H. Hutton—Lightning and Lightning Protection Apparatus.
E. W. Hyman—Direct Current Heavy Traction.
L. G. Ireland—Polyphase Induction Motors.
E. W. Kay—Direct Current Armature Design.
A. D. LePan—Management and Economics of Electric Stations.

D. J. McGugan—Protective Apparatus for High Tension Power Transmission.

F. W. McNeill—Individual Motor Drive and Speed Control.

L. R. Miller—Single Phase Railway Work.

G. E. Quance—Hydro-Electric Power Installation.

E. R. Smithrim—Electro-Plating and Electro-Chemical Refining of Nickel.

A. C. Spencer—Internal Combustion Engines.

O. R. Thomson—High Tension Line Construction.

E. D. Tillson—Electrical Distribution (underground work).

A. F. Wilson—Electric Railway Motors.

J. N. Wilson—Power Transformers.

E. M. Wood—The Control of High Potential Systems.

WHAT THE GRADUATES ARE DOING

On this page we shall be pleased to publish *professional* news of any of our graduates.

It is impossible to keep a good man down. F. W. (Casey) Baldwin, '06, is associated with Professor Graham Bell in his experimental work on air-ships.

J. T. M. (Thrift) Burnside, '99, is pursuing his profession in China.

The stringency in the money market has forced a number of our graduates out of employment. One compensating feature, however, is that they have seized the opportunity of renewing old acquaintances around the University.

E. A. James, B.A.Sc., '04, took over the editorship of the "Canadian Engineer" at the first of the year. If he puts one-half the enterprise and energy in the journal that he put into the Engineering Society, great things may be expected in the future. The "Canadian Engineer" is to be congratulated on securing his services.

W. F. Wright, '04, has been promoted to Chief Engineer, Denver District General Electric Co. His headquarters are Denver, Colorado.

W. S. H. Keefe, '04, is manager of the Fort Covington Light, Heat and Power Co.

F. Grant Marriott is chemist and superintendent of the asphalt plant for city of Toronto.

M. S. Culbert, '02, is manager of the O'Brien mine, Cobalt, Ontario.

R. (Bob) Bryce is manager of the Silver Queen.

Wm. F. Ratz, D.L.S., '02, is on the staff of International Boundary Surveys. For the past three years he has been engaged in the survey of the International Boundary between Canada and Alaska.

Rutherford Cummings, '02, after being associated with

Haney & Miller for some years, has started business for himself as a general contractor. One of his first contracts is the new Ontario Government Experimental Sewage Station.

William G. Chase, '01, is a member of the firm of Smith, Kerry & Chase, Confederation Life Building, Toronto. His firm was consulted in the estimates for municipal power distribution plant for Toronto.

Toronto graduates are playing an important part in the electrical development of the country, including the plants at Niagara, where all the power companies, including the American, have employed school men extensively. The Canadian company, with that loyalty which is characteristic, have employed foreign talent almost exclusively.

Arthur Laidlaw, '01, is a district manager of the Trussed Concrete Steel Co., with headquarters at Kansas City, Mo., and Omaha, Neb.

D. E. Eason, '01, is district engineer, Trent Valley Canal, at Peterboro.

William Hemphill, '00, is general foreman for the Cataract Power & Conduit Co. at Buffalo, N.Y.

W. Almon Hare, '99, is secretary-treasurer and chief engineer, Standard Engineering Co., Toronto.

H. V. Haight, '96, is chief engineer, Canadian Rand Drill Co., Sherbrooke, Quebec.

Gordon M. Campbell, '96, is superintendent Western Electric Co., Chicago.

Harold Rolph, '94, is vice-president, Metcalf Engineering Limited, Montreal.

L. E. Charlesworth, '93, is Director of Surveys, Edmonton, Alberta.

"YE LADY ENGINEER"

*"Laughter and tears are meant to turn the wheels of the same machinery of sensibility; one is wind-power, and the other water-power; that is all. * * * * The ludicrous has its place in the universe; it is not a human invention, but one of the divine ideas."—Autocrat of the Breakfast Table.*

(Illustrations by W. Van R. Reynolds.)

Dear Sir,—Your communication of the 20th ult., announcing my appointment to a Special Comimttee to report upon the admission of lady members, duly received. As requested, I have carefully noted the information given, as follows:

Item 1. Prof. Starr, of Chicago University, in a very widely reported lecture, declares that women students have a stronger grip on mathematics than the men, and that the men are more emotional than the women.

Item 2. The "Technical World," October, 1906, announces that Miss Nora Stanton Blatch has been elected to membership in the American Society of Civil Engineers; also that

Item 3. The University of Colorado has recently graduated its first woman engineer.

Item 4. A late "Engineering News" records the fact of Miss Elsie Bittman having vacated a $1,200 draughting position in the New York City Bureau of Highways for an assistant engineership on subway construction.

Now, Mr. Editor, if you will allow me a few lines in which to air my views upon the foregoing, you will partially excuse, I hope, my slowness in deciding to act on this Special Committee.

The facts set forth in your letter presumably are intended to convince me that the old order is changing, and that it devolves upon the Applied Science to act in recognition thereof. There certainly does seem to confront us some necessity for alteration in the scheme of things entire—nowadays when we can sit at home and listen to Patti and Melba sing vulcanized rubber songs merely by twisting a crank. But, if it comes to that, where are the copper buns of yesteryear; whither vanished the old-fashioned, particolored sugar stick of tooth-irrigating memory? The stage and the old grey mare going out, and the railway and motor car coming in, means, as someone says, that we arrive at places now, we travel no more. Our pet theories, too, are exploding one by one—deny it we cannot. Modern research is seeking to impugn the rosy cheeks of Newton's apple; to repeal the very laws of gravitation, despite the evidence obtained by the centre of gravity of our waistcoats in a Trader's Bank elevator. Waterfalls, we have discovered, have other uses than to form picturesque pickerel pools; they who seek them out at present writing are promoters and their engineers, and have other fish to fry. But what of the matter more particularly in hand? It seems, then, that in the land to the south they are rushing it to the limit—this *Age* which answers to the equation of—

Criss-cross + catacorner = F + topsy-turvey + higgledy-piggledy; F being a constant representing the date, last past, when the moon was at the full.

In other words, a dimpled trio of comeliness—after publishing the banns for four academic years and a post-graduate course—has become wedded to the engineering profession, following the example of others of the fair sex, who, in other lines, have been united in the holy bonds of making money. They have gone Dr. Mary Walker one better; such appears to be the case.

For my part, wondrous had it seemed had some giddy young damsel in fluffy bangs, beholding lady doctors and lady lawyers and lady such-and-such—every one prospering—not grown clamorous, not longed to conquer the realms of practical scientific intellectuality; to take things out, as it were, to the "henth" power; not yearned to be a mining expert, for example, to go romping after rugged rocks with dinky, diminutive hammer, or to practice civil ingenuity, perchance to prod into the vital statistics of sewers and pavements and septic tanks and so forth, and do telescopic stunts for a microscopic salary, while figuring on the *dramatis personæ*" of a Government survey, just like many of the lords of creation. I could have told you so. Satan finds some mischief still for the hand that rocks the cradle.

This Chatauqua business was bound to be overdone. Airy, fairy Lillian, once she cultivated a bowing acquaintance with long-legged words ending in *-osity* and *-ism*, would be sure to pursue the downward path, and ere long stumble against an introduction to specific gravity and voltage and such like. When she commenced seeking the mother-lode of erudition, from acquiring the Latin word for a water-beetle—don't you know—to reading periodicals infested with higher mathematics, and cultivating a craving for strength of materials and conic sections, the gradient is remarkably easy. The seed had been scattered, the soil was fruitful, one had but to squat on a roadside stump and take an observation of the harvest.

While still in frocks that flirted with their boot-tops, they had read their Tennyson—these saucy, winsome lassies—probably knew him all by rote, most of them, and in a desire to throw off the "sooty yoke of kitchen vassalage" can you marvel that a few gathered up their skirts and jumped the fence into the engineering field? Was there any reason why they could not take 2 and 2, and multiply them together, and dally just as learnedly as the men with the finished product. Nay, nay, Pauline. Not by a back sight!

So, from her mother's kitchen my lady charming passed to the school of technology and the laboratory thereof—gathering lore ament the intricate fusing of metals, eating of the tree of knowledge of the *entente cordiale* between Sodium and Magnesium, and getting wise to the proposition that Cobaltite and Nicolite moved in the same set.

It was only the merest step from the rolling pin to the parallel-ruler; from being a dab at domestic functions to proficiency in functions algebraic—the slitheriest sort of lubricated transition; from being chief push at a Domestic Science meeting to reading a paper on some such subject as "Reinforced Cow-meat" was like sliding off a log. Fish-plates and fashion-plates are confusing in shorthand. Beet roots and cube roots nearly are allied.

Looking abroad, then, and rolling a melting eye, and rubbing shoulders with successful female barbers and dentists, it was nothing but natural for some ambitious Alice, or Priscilla, or Phyllis, or Eunice, to hazard a bet in an idle moment that she would yet reach the head of engineering navigation, and snug fast in one tender, loving hug of exceeding largeness, to the fat salary that environs the crafts and subtleties of the consulting engineer.

The men have only themselves to blame, perhaps. Here, for years they have been practising deceit. The ladies were sure to find out after a time that a dam is not merely a long, low, splashy-looking thing with green moss and poetry and stuff on it, where the boys have their swimming hole; but also that good money may be made at home by figuring and making plans about it before it is built and flops over. Nobody likes being gammoned, and that's why the gentle, adorable Doris is elbowing the men and stooping to the profession—why woman, lovely woman, is bringing herself down to a mere man's level, and transit.

There is no use telling the dear creatures, these sweet and radiant handmaidens of Science, what they are up against, I suppose. If they knew the tariff charges, unless I miss my guess, it would be a kissing game of good-bye to the civil enginine. However, as the profession claims as many different varieties as Heinz's pickles, it may be assumed that there's a lot of gentle-eyed gazelles perched on the verandah and watching to see if this first bunch of beauty makes good before taking the plunge. If one brand doesn't seem appetising, there's a lot of others left. That's doubtless what they think. Ruth crushed to earth will rise again. But, being kind-hearted, I sadden, I hasten to drop the unfeigned tear! Could a thought more hateful than leaving them to fry in their own fat be imagined?

I suppose the whole crusade started with that disinherited tradition about the Transit of Venus, and how Venus laid out the Milky Way, and the further discredited idea that she gave her arm to make the third leg of the tripod. Or have they gone crazy from playing bridge?

Mercy me, what wielding of logarithms with the energy that should flow in full, free, fast flood, undefiled, toward the carpet sweeper! What cluttering of feminine brains with labyrinthine formulæ! What acquisition of wrinkles over Chambers' Tables when the time were better employed in ironing wrinkles out over the tables in the laundry, must ensue, ere these poor, deluded but beautiful blossoms of loveliness realize their mistake, acknowledge that it is better far to know how to scale a nice fresh herring than a plan—not to say, bake a tapioca custard than cook field-notes.

After all, my dear Mr. Editor, the point I make is, that what has come to pass is not in our own country. The germ has been isolated and propagated, let us admit, more or less successfully under the Eagle's wing; but it is all experimental, and from Uncle Sam's domain to ours is a far fly. Upon mature deliberation I consider Applied Science unduly excited and tanbarking up the wrong tree. I grant, of course, the advent of a new era, and that Canada is going to loom large; that "with enormous untouched natural resources," etc., already has she begun to bring her pigs to market—and billets, too—and that no longer will we sit down and say grace over bare bones. All of which signifies that the day of the engineer and surveyor is here.

It is true that many young ladies have come from Toronto University with the centre B and distance B.A. in their bonnets—have done so for years—but reading Moderns, and Kant, and messing round the fourth dimention and such like, is different to having technical and mechanical fal-da-rals seething in your brain-pan. If a fellow like me, who is trying to get three squares a day out of engineering, may be permitted to have such grave, mighty thoughts locking through his cogitatory canal, I should say that our maidens can be *tete-a-tete* with Macaulay and Gibbon without interfering with the artistic *tout ensemble* of the stuffed canaries on their Sunday morning hats; yet that these same sweet lady graduates are too sensible to fail to understand how the paths of survey lead but to grey hairs; how working fakes with a lathe, or frivoling with bridge construction or twisting on or off the juice in a power house, are things better left to brother Tom. We bring our daughters up better. We do not want to be reading advertisements of ''Maiden Canada'' engineers.

There is the eternal fitness of things to be considered, despite the fillip given to some minds by the quaint, the unexpected. ''A Madonna of the Sand Pump'' would not look right. Resolved, that a horn spoon is the best for the mustard pot; also that ginger beer tastes better from a stone bottle, whilst the ordinary hayfield variety of beer—accepting the knowledgeable dictum of the immortal Bob Sawyer—yields its ultimate strength, imparts its most delicious, nut-brown quintnnessences to the wetted perimeter known as the right spot, only from ''it native pewter.'' Nay, a plumb-bob would not feel at home waggling at the end of a corset string. It is all very well for the ''Technical World'' man to get busy and make statistics for printers' copy. But stop for a moment and consider the absurdities of it all!

Picture your draughting office! A dainty, demure, tender dove of a damsel over there in the corner, with a prodigal wealth of auburn tresses her head adorning, and a truncated cone of ditto behind—impressionable, she, as a fresh-trowelled concrete walk—just fancy her, intent plotting curves for permeability and calibration or efficiency and power factor, or some other thing, and lining her snow-white, patrician brow till it resembles a terminal yard; the fair, pure oval of her face tuck-pointed from chewing gum; with it all an intangible yet prevading aroma of lavender or new-mown hay in the air! Is't not a presentment to set you a-dreaming of lyrics and sonnets and strophes! ''And they called her Maud.'' The drawing room! ''Imagination fondly stoops to trace the parlor splendors of that festive place,'' as per the poet. What ashape your papers would get into—estimates jabbed together with safety pins and what not. Under the regime of one's able assistant, Miss Fluffy Ruffles, Spinster of Applied Science, would not one's reports and specifications have more postscripts than a steel tape gets kinks? Just think, think—let your fancy have play—the walls! Bunches of celluloid set squares and French curves tied up with baby ribbon. My very soul is harrowed. What insertion in the drawing paper, what tucks taken in the cross-sections, what three-inch pleats in hemstitched profiles, would signalize the invasion of sighing Jean, or cooing Dolly, in her Peep-a-view shirt waist, and side-stepping hither and thither, flaunting, fluttering—with a mouthful of drawing pins! 'Ods precious; only conjure up the stuff you would always be finding on your best embossed letter-paper after she had gone for the evening, an' it please you. She would set up her muse, and level it, and run "Lines to a Gravel Pit" after some such fashion as:

> "Oh, to be carted away
> From this dark Aceldama of sorrow,
> Where the gravel and sand of to-day
> Becomes the concrete cub. yd. of to-morrow."

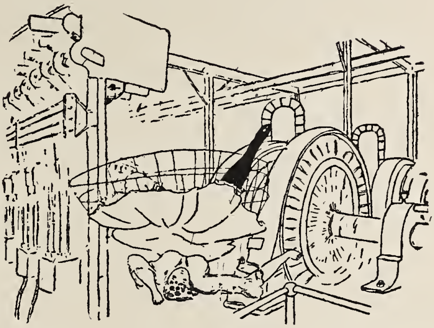
Would you like that? Would it be seemly? I grant that plenty of our draughtsmen lack the brains of a horse on a milk route, and that now and again one might count on an artistically-minded female who could manage a plan which when completed didn't look as though its necktie were up over its collar, but—my word for it—the lady draughtsman is yet a long way off. Do you think they would ever date a drawing? No, the betting is 20 to 1 against pink T-squares. There are too many other congenial occupations—if they will not stay at home and help mother, and recreate with *Trolley-era Rusty-piano* sort of music when Mr. Smithkins calls of an evening—too many vocations for them to confess to any wistfulness for a bridge, or languishment for a five-mile breakwater, or love for a septic tank, or desire for a bevy of culverts. And if the Engineering Society is serious it surely must be holding the telescope to its bad eye.

Their common sense will teach the ladies that digging ditches and cumbering the earth with viaducts are not for the likes of them. Our Lady of the Snows (be the last same, more or less) has no hankering to go roaming up and down creation jabbering about test-tubes, and assays, and load-factors, and shaft-sinking, *et al*, like a lather with a mouthful of nails. They recognize that a pretty girl and plane trigonometry—be the moon ever so lovely—are incompatible, incongruous.

Why, the idea is so silly! First thing, we'd be having "Rules of Professional Etiquette on Sewer Work," and a new column in the "Ladies' Home Journal," headed "Complexion Aids for the Field." The longer I ponder the whole proposition, the more decided I become.

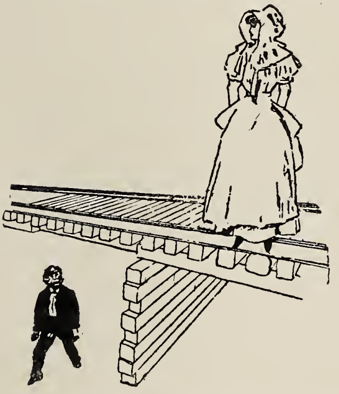
Hark! list!—do you hear the pathetic, undertone query, "Is my instrument on straight?" Ludicrous, crazy, the entire hypothesis!

Behold Gladys Edythe—tricksome goddess, serenely sweet—wrestling on a cold, windy day with the thumbscrews, in a pair of No. 6 suede gloves, the whiles her dainty tailor-made gown plays clothes-line with the tripod. Gaze on her trying to negotiate the elusive cross-hairs, what time her feather is frisking between the bubbles like the swipe of a Newfoundland dog's tail. . . . I believe that there are a lot of other girls who affect squashy, deep-apple-pie kinds of headgear, with a chop suey adjunct of violets, or assorted fruits, or something clinging to the soffit of its *porte cochere;* but if we can imagine a lady surveyor or engineer at all, in either case—if she were giving line and god mad and tore it off and threw it down and jumped on it—the resultant would be the same by the graphical method.



Suppose crinolene to come in, and Alicia in a power plant! She'd go fooling about—blonde curls, cunning curls—get caught in the shafting or make a short skirtlet, and just then things would be hooping up generally.

Think of her measuring on a trestle, with notebooks and powder puff, and tape and pencils, and red chalk and smelling salts, and the usual incidentals in her chatelaine. She'd be yelling in a rich deep mezzo-soprano to Kelly, the foreman, to yank those ties off quick, or get to the calorific equivalent out of that. Would Kelly, think you—whose language, when he is caught without an umbrella in a brainstorm, is often so bad that his mouth needs a mud-guard—be apt to study fastidiousness in his repartee to those pearly cadences issuing from those ruby lips? Deponent sayeth not, nor yet putteth it in writing.



The foregoing, my dear Mr. Editor, are but the more obvious things that occur to me. I am not going into delicacies. But love my heart alive, would not every survey demand a chaperone? Ye gods, what a vision!

No, doubloons to ditch-water, 'twill be a long, long day ere the saying changes to "Oh, for blue prints like my mother used to make." The civil enginine's contract is too much inclined to *embonpoint*, and we need fear no foe in the guise of a moth-ball rolling care-free in the tracing-cloth drawer. Winging to covert in the technical section of the "Idle Rich" is a grown man's job.

And all of the above, Mr. Editor, makes me opine that the Engineering Society need not let worry sit too heavy on its chest. After reading same, if you still think the Committee necessary, and that it's up to me to act, you have only to say the word.

With best wishes, believe me,

Yours truly,

E. C. EASY, C.E.

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THE GROUNDED NEUTRAL AS APPLIED TO TRANSMITTING AND DISTRIBUTING SYSTEMS

W G. CHACE, '01

The primary objects of grounding, in general, have been to save cost of complete metallic circuit; to prevent destruction of life and of apparatus. The first use of electric current was for the purposes of communication by telegraph, when low voltages were used and but one conductor was strung between the terminals of communication. Considering the high resistance of the metallic conductor used and the small amount of current involved, the ground return formed a very satisfactory portion of the circuit. This system was also applied to the earlier telephone circuits which had the field prior to the introduction of electric lighting distribution or of railway systems.

The ground return via the track rails, unbonded, and adjacent earth was used in connection with the earlier electric railway systems; and the grounded rail, thoroughly bonded, is now an element of the circuit of nearly all electric railway systems in use, both direct and alternating current.

In connection with the distribution of electric currents for lighting, the grounding of one side of the circuit was occasionally resorted to, but this practice was frowned upon by the insurance companies as likely to become a source of fire risk. but with the introduction of the (Edison) three-wire system of electric lighting in the days when direct current alone was used for this purpose, the practice of grounding the middle or "neutral" conductor was resorted to very freely; and when the use of the direct current was to a large extent superseded, and everywhere supplemented by the more convenient alternating current with its transformers, the Edison principle of three-wire circuits being made use of on the low side of the transformers, the neutral was at first permitted to be grounded, and during the last two or three years it has been distinctly urged by the insurance companies that it be grounded, with the double object of immediately discharging high voltage which may, through fault of the transformer, reach the low potential circuit, and of protecting life.

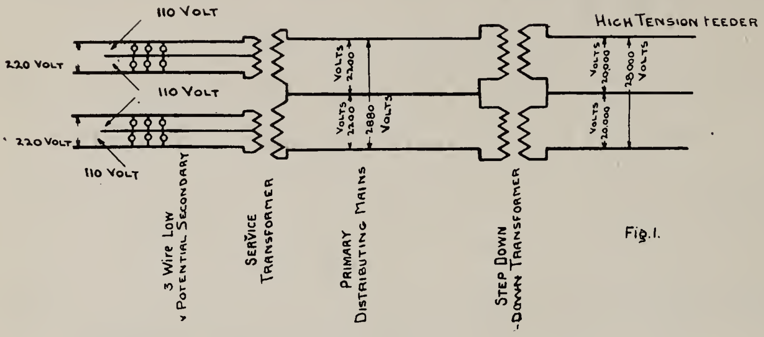


Fig. 1.

Here with all sections of the system indicated ungrounded, there is danger of the high voltage from the 20,000 volt mains crossing into the 2,000 volt circuits, as also of the 2,800 volts of the three-wire, two-phase, 2,000 volt (so-called primaries) transgressing upon the 220-110 volt secondaries; but with the grounding of the middle wire of the low potential secondary distributing circuit, there is little danger of disaster other than to the transforming equipment.

The reader is referred for a fairly concise discussion of the grounding of constant potential systems to a paper by Hood in the Electrical World for 1904, volume 43.

1. The neutral point is not always accessible in the ordinary equipment of transformers for high potential transmission or distribution. (See fig. 2.)

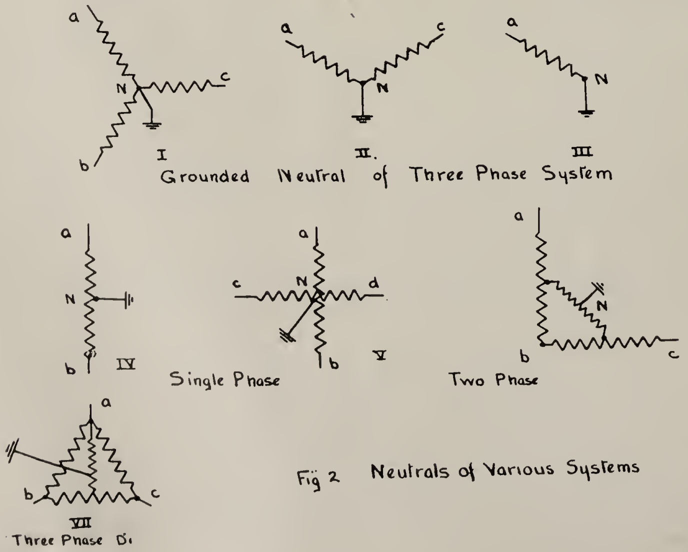


Fig 2 Neutrals of Various Systems

In a single phase transformer a special tap must be brought out from the middle point, but should it be desired to have a number of optional working taps at one end of the high potential winding, this middle point is not always the middle point electrically, but it would serve as a point at ground potential which could conveniently be connected to the ground. In a two-phase, four-wire system, the taps from the middle points of the single-phase transformers used could be joined together and to ground; but in two-phase, three-wire system it would be necessary to make use of an auto-transformer, tying together the middle points of the single-phase transformers, and from the middle point of this auto-transformer to obtain a point for grounding. In a three-phase star connected system the common point of the star serves conveniently for grounding, but in three-phase delta connection it is necessary to make use of an auto-transformer connected from the junction of two phases, for instance A and B to the middle point of phase C, from which auto-transformer at a point one-third of its winding from phase C a grounding could be made. This method of obtaining the neutral point from an auto-transformer is almost never resorted to on account of the expense of the auto-transformer.

The purpose of this paper is to place before the Society a summary of the readily available American literature on the principles and practice with regard to grounding the neutral point in transmission and distributing circuits.

The various objects to be served by the grounding of the neutral in high potential alternating current systems are:

1. (a) To maintain constant the potential of lines to ground, in order
   (b) to protect apparatus, and thus
   (c) to minimize the interruptions to the circuits, by
   (d) making possible detection and thus removal of undesired grounds;
2. To prevent abnormal static induction upon neighboring circuits;
3. To make the ground (return) available as a working conductor;
4. To make the condenser current per phase uniform, and thus to prevent high static voltages upon the circuits.

The above summary of the objects in grounding the neutral is largely taken from a paper given by Paul M. Lincoln in October, 1907 before the New York Section of The American Institute of Electrical Engineers.

In reference to 1 (a) and (b), it has been held by some that the grounding of the neutral, for the purpose of maintaining a constant difference of potential between each wire of the circuit and the ground, will permit the use of cheaper insulation, but it has been fairly well shown in practice that it is not the ordinary operating conditions and accompanying normal voltages which limit the insulation desirable or required, but rather the abnormal stresses set up either through induced changes on the line, or by the opening of circuits in switching, by breakage of a conductor, by accidental grounding, or through real short circuit. Mr. Gerry of the Missouri River Power Co. has pointed out that the earth resistance between grounds often throws full line potential on the line insulation. In this connection reference is made to a very complete discussion of the possible voltages, abnormal voltages and currents in high potential transmission as dependent in ordinary practice in construction upon the length of the line and upon the constants in the individual cases, all as described by Ernest J. Berg, of Schenectady, in a paper read before the Schenectady Section of the American Institute of Electrical Engineers on January 31st, 1907. Mr. Berg shows that for overhead transmission at high potential the instantaneous voltage rise due to the breakage of the circuit is per phase above ground potential, the quotient obtained by dividing the instantaneous value of the current in amperes by 325; and, conversely, that when high voltage be thrown upon a dead transmission line the instantaneous value of the current which flows is the quotient of the instantaneous value of the electromotive force divided by 325, i.e., for average value of inductance and capacity; he also draws attention to the fact that these current and voltage values may exist in grounded as well as ungrounded systems. Mr. Berg further shows that in case of a slight leak of current, through switches for instance, especially if that leak take place through an inductive path, that the potential of the conductors of the circuit above ground may be tremendous, and he therefore advises that in all high potential work the advantages of a grounded neutral be taken advantage of, and through a non-conductive path.

An important advantage in maintaining the normal potential of the conductors at a definite electric distance above ground lies in the fact that the to date accepted lightning arresters, which consist of a series of very small gaps in conjunction with non-inductive resistances, may be closely adjusted so as to relieve the line with moderate increments of potential, and thus serve most completely their protective function. For example, in a 60,000 volt three-phase circuit, ordinarily the potential of each conductor above ground is about 35,000 volts. Evidently, if the neutral of the system be not grounded, and one of the three wires should become grounded, the other two wires would immediately be raised to a potential of 60,000 volts above ground, so that with this class of circuit it is necessary that the lightning arresters should discharge with a potential above ground of say 75,000 volts, whereas with the same factor of protection in a system with grounded neutral the lightning arresters could be adjusted to about 45,000 volts to ground, and destructive voltages would then be prevented from appearing upon the circuit.

In this connection it is desirable to read carefully a very thorough discussion by Mr. J. S. Peck before the American Institute of Electrical Engineers at Niagara Falls, N.Y. on July 1st, 1903. Mr. Peck shows with very great completeness the possible voltages likely to appear on account of the accidental grounds on one conductor, in circuits with grounded and ungrounded neutrals. This discussion of Mr. Peck's is very well illustrated and rather clearly set forth, but it must be kept in mind that a considerable number of the combinations which are analysed by Mr. Peck are for various reasons undesirable, and therefore almost absolutely unused. Such, for instance, as the YY connection of the transformers, excepting where the neutral of the step-up Y is connected to earth, not only at the transformer but also at the generator.

With reference to 1 (c) and (d), the attention will be drawn below to the experience of a number of companies, which have been operating, transmitting and distributing systems, some with and some without grounded neutrals. It has been found that with most systems the faults most commonly appearing is a grounding of one conductor. Should the other conductors of the circuit be in such proximity to the faulty conductor that the fault can communicate itself to one of those conductors, a short circuit between phases immediately results, and the full power of the generator, or of several generators, if operating in multiple, is concentrated upon the fault, and considerable destruction follows. Now, with the neutral of the transmission system grounded, the first ground which commonly has a path of considerable resistance, indicates itself in the station as a short circuit of great or little intensity upon the transformer forming that phase, or upon the generator if no transformers intervene, and if the resistance of the fault be sufficiently low automatic switches will open the circuits and relieve the trouble. A careful examination of the results, some of which are outlined below, of operating distributing systems with grounded neutral would seem to indicate that by this means the severity of the disturbances due to accidents on the circuit, and the destruction of the conducting system by these accidents is very materially reduced. so that the minimizing of the delay in resuming the use of the injured circuit is a very material gain, where continuity of service is so important, as it is in all systems supplying a high-class load, especially in large centres of population.

On the contrary in many systems, especially those whose circuits are wholly aerial, it is considered to be very undesirable that every ground should be a short circuit which, in operating automatic devises, interrups the service. Frequently an operator will prefer to risk damage to his apparatus rather than surely cut off his customers, when he knows that even with one conductor grounded he can continue to serve, in the meantime arranging for the removal of trouble indicated by his detectors.

2. Generally speaking, there are two classes of interference with neighboring circuits such as telephone and telegraph cir-

cuits, which interferences are due to the operation of high potential alternating current systems. These are those of electrostatic induction and electromagnetic induction. In the ordinary three-phase circuit there is an almost balanced series of static charges of elecricity on the conductors as against ground, the air acting as the dielectric of a condenser. Without a grounded neutral an accident grounding of one line of the circuit very seriously unbalances this system of static charges, and upon other metallic circuits within the range of the transmission circuits there appear a very considerable series of static charges also as against ground, sometimes sufficient to prevent the satisfactory use of those parallel circuits. The grounding of the neutral of the transmission circuit will prevent very serious electrostatic disturbances upon parallel circuits.

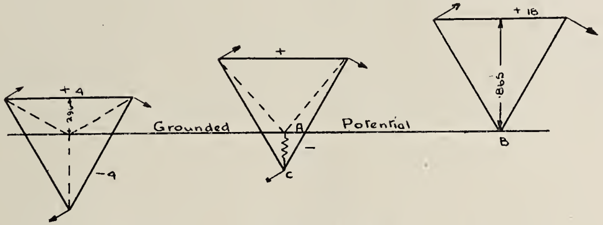
The electromagnetic effect of a high tension transmission upon parallel circuits is not materially influenced by the grounding of the neutral unless the earth carry current, as it would if used as indicated above in fig. 2, II and III. While ordinarily in an insulated circuit the electromagnetic effect upon parallel circuits is negligible, if the earth be acting as an element of the power circuit, the inducing loop bounded by the other conductors and the earth, being of a large area and dissymmetrically located with relation to the influenced circuit will set up very considerable electromotive forces in that circuit. Here the grounding of the neutral is a disadvantage, whose weight must be considered.

A clear discussion on this subject of the influence of power circuits upon parallel ones is to be found in the transactions of the American Institute of Electrical Engineers in papers by P. M. Lincoln in 1903.

3. The ground is some transmission systems commonly made use of as a working conductor in connection with the grounded neutral on the high tension side of the step-up transformers. In certain thinly populated districts where loads are sparse and small, the requirement of electric service can be met by use of the cheapest methods of construction. A single wire or, in cases of larger power, two wires of a hree-phase star connected system can be run out to the site of the customer's premises, and fairly satisfactory results can be had.

4. In the discussion by E. J. Berg above referred to it is shown that the lack of a ground at the neutral point is sufficient under the conditions of a ground on one conductor of the high tension circuit to set up very serious potential stresses between the generator windings and ground. A discussion of this source of troubles in generator and transformer windings is found in the *Electric Journal* for 1907, page 646, and in the same magazine for 1908, page 84, in papers by R. P. Jackson. (See Figs. 3 and 4.)

Briefly, Fig. 3 represents by a rotating triangle, first, the static condition existing normally, in which case the total charge to the ground is zero, and no current need be supplied from ground; second, the conditions existing in the case of a high resistance path to groundbeing established, in which event considerable current flows to the circuit through the fault; third, the conditions existing in the case of a "solid" ground, or one of zero resistance. In this latter event, with no grounded connection on the system, the effect is as indicated in Fig. 4. The transformer bank windings and the generator form two condensers in series, across which the static potential is divided in inverse proportion to their capacities, so that in case all windings be insulated from ground, and if the capacity of the generator windings to ground be small in proportion to that between the transformer windings, as would be the case for one generator operating on several paralleled banks of transformers, the stress of potential on the generator windings might puncture their installation. This condition of affairs can be avoided by grounding the neutral point of generator windings, preferably through a low resistance as suggested in Fig. 4.



Conditions Normal High Reistance Ground Solid Ground

Fig 3

Static conditions in Three Phase Delta Circuits

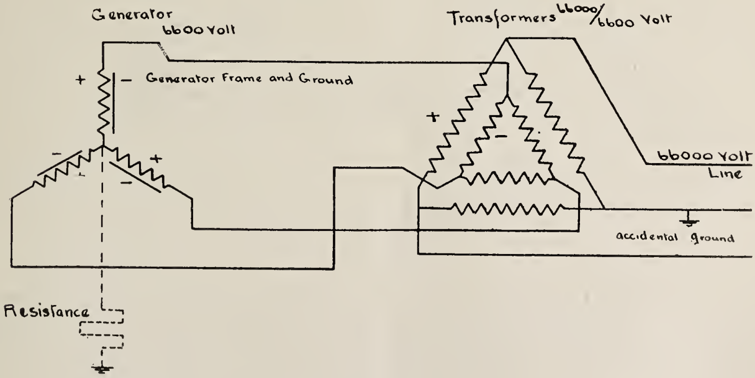


Fig 4

In Fig. 5 (taken from the paper on "The Grounded Neutral," by P. M. Lincoln, presented before the American Institute of Electrical Engineers at New York in September, 1907, is shown diagrammatically the magnitude of the capacities existing between lines and between the lines and ground in a three-phase system. With the lines thoroughly insulated from each other and from earth, and with neutral grounded or ungrounded, the currents flowing through capacities C are equal and their sum is zero. The sum of the kilovolt amperes in these paths is proportional to the product $3(CE)E$ or $3CE^2$, where E is the potential to earth. With the neutral ungrounded, and with a fault of zero resistance on one high tension conductor, the sum of the kilovolt amperes in these condensers is $2(C\sqrt{3}E)\sqrt{3}C$ or $6CE^2$. This is serious change in the state of the current if the lines be long and the potential of transmission high, and the result would further be a serious disturbance of the voltages in the three phases. Grounding the neutral point of the circuit would prevent this, while, of course, the development of a fault would

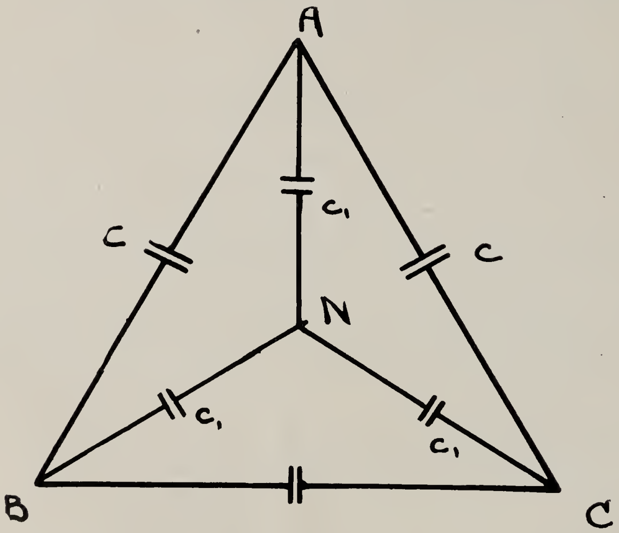


Fig 5

mean a dead short circuit on one phase. In passing, it may be mentioned that in his discussion of the Lincoln paper, Mr. Philip Torchio describes a detector which has been applied to the high tension cable feeders of The New York Edison Co.'s system, and in which device this disturbance of capacity currents is made use of to indicate the presence of trouble.

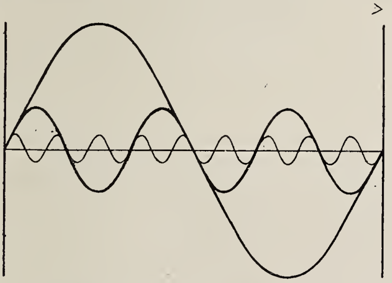
5. The method of grounding the neutral lead has been the subject of very considerable difference of opinion. All are agreed that to be effective and safe, the ground connection itself must be good; its resistance must be low and uniform, and it should preferably be kept continuously moist. But whether to use definite resistance

in the ground lead, whether to ground the neutral at more than one place, and whether to ground each generator unit or no has been much disputed. The discussion of this subject at New York in October, 1907, following papers before the American Institute of Electrical Engineers, by Messrs. Lincoln, Rhodes and Clark, was quite illuminative.

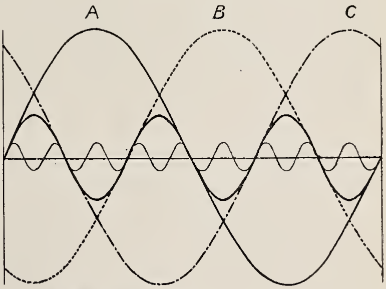
It was generally accepted that the connection to earth must be made with a minimum of inductance; it is fairly clear that the resistance in the path to earth must not be high, otherwise when current flows in the neutral lead of magnitude sufficient to influence automatic protective devices, the drop of potential therein will be so great as to defeat the end aimed at, namely, the prevention of abnormal differences of potential between the earth and ground. Some operators make use of a "solid" ground, i.e., one without reistance.

The resistance used must be or large carrying capacity, of uniform dimension, and mechanically strong. Iron grids have served satisfactorily.

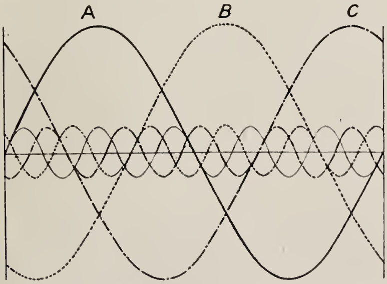
Attempts have been made to ground each generator of a bank operating in parallel, but the cross currents in the neutral lead have been such as to make this method very unsatisfactory, and in some cases unworkable. The explanation of this feature is made easier by a reference to Figs. 6 to 10.



PHASE A
3D AND 9TH HARMONICS
FIG. 6



THREE PHASES
3RD AND 9TH HARMONICS IN PHASE
FIG. 7



THREE PHASES
5TH HARMONICS OUT OF PHASE
FIG. 8

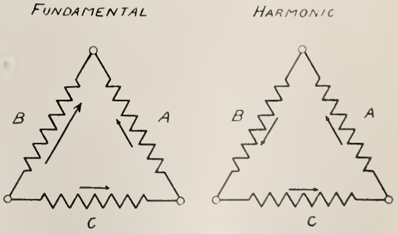


FIG. 9

In Fig. 6 is shown a fundamental wave of potential, and its third and ninth harmonics; in Fig. 7 are shown the fundamentals of three phases with their third and ninth harmonics. It will be noticed that these harmonics are in phase for the three phases; as drawn the harmonics are at zero coincidently with the fundamentals, but this is not necessarily or even probably true. In Fig. 9 are shown the relations of the fundamental and of the third harmonics at a given instant in the windings of a delta connected generator. It will be noted that the third harmonic does not appear outside the generator windings, but sets up a circulating current in the windings. In Fig. 10 are shown the relations of the fundamental and of the third harmonics at a given instant in the windings of a star connected generator. As these harmonics are in phase, they neutralize each other, and do not cause a flow of current in the outside circuit. However, should the neutral of this generator winding be connected to ground in parallel with that of another star wound generator connected to the same working bus bars, there would be an interchange of currents of triple and multiples of triple frequency between the generators, unless, as is unlikely, the phase relation and amplitudes of these harmonics be identical. It may be noted that it has been reported that certain steam turbine driven generators have been so connected without interchange of currents via the neutral leads. A full development of these conditions is given by Mr. A. G. Grier, of Montreal, in the *Electric Journal* for 1907, page 189, from whose paper these diagrams have been taken by his courtesy. In Fig. 8 is shown the non-coincidence of the fifth harmonics of the three fundamental waves of electro-motive force. These harmonics, along with other harmonics of a frequency described by an odd prime number, may appear in the external circuit to modify the form of the wave of electromotive force between main conductors.

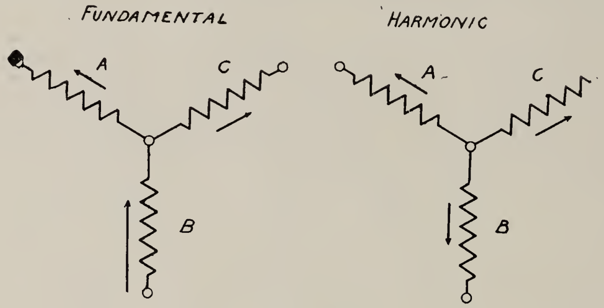


Fig. 10

6. The literature dealing with the experience of operating companies with the grounded neutral, covers chiefly systems distibuting power in large cities by means of underground and overhead circuits. Those reported most fully are that of the Interborough Rapid Transit Co. of New York City; that of The Long Island

Division of the Pennsylvania Railroad System, and that of The Commonwealth Edison Co. of Chicago; that of the Cincinnati Gas and Electric Co. has been reported briefly. The latter two companies have been operating with the neutral grounded since 1900, and Mr. Eastman, in speaking in 1904 of the experience of the Chicago company, stated that the advantages of having fixed the maximum potential above ground, and of the ease of locating trouble on the circuits, overbalance the dangers due to the fact that an accidental ground on one phase is equivalent to a short circuit. That company have both overhead and underground high tension lines.

The Interborough Company have operated since 1905 with a grounded neutral. Previous to that year their experience had been that nearly all faults in their distributing system appeared, first, as a "ground," afterwards developing into a short circuit after the flow of charging current through the fault had destroyed the insulation of the feeder cable. The evidences of trouble were usually discharges of "static" electricity at the substation or power station end of the cable, often unnoticed until the short circuit opened the feeder switches. This happened with considerable violence, sometimes resulting in the destruction of the switch. The rush of current back into the fault from the rotaries in the substation often opened all feeder switches and shut down the station. It was usually very difficult to locate the trouble, and much time was lost in so doing; this difficulty arose through the amount of destruction accomplished at the fault. Since grounding the neutral of the system, it has been found that a fault in the feeder cable usually cut out the cable quietly and little destruction of cable was wrought by it, so that it has been possible to soon get the cable back into service, repaired. For details of the experience of this company with and without the grounded neutral, see Rhodes' paper before the American Institute of Electrical Engineers, October 11th, 1907.

Grounding was done through a resistance of large current capacity, and of sufficient magnitude to limit the current flowing through the fault. At first all generators were connected to the neutral bus, which, in turn, was earthed; but the interchange of currents of triple frequency through the leads to the neutral bus was so great an annoyance that now but one generator in each of their two stations is grounded.

The New York and Long Island Railroad Company have had in operation an 11,000 volt, three-phase system, partly overhead and partly underground, for about two years. The neutral of this system is grounded through one generator lead with a resistance of 6.7 ohms. Their experiences are described in Mr. Clark's paper, read before the American Institute of Electrical Engineers on October 11th, 1907. It is declared to have been successful, but certain disadvantages are indicated to accompany the use of a resistance in the neutral lead, chief of which are that on occasions the current through the fault may be so small that it will not open the switch in the faulty feeder, and that the drop of voltage across this resistance is so great as to make the potential of the other conductors of the circuit to ground very great.

The practice of the Commonwealth Company is described by Mr. P. Junkersfeld in his discussion of the above-mentioned papers. This company operate two classes of high tension service, a four thousand volt, four wire, three-phase, sixty-cycle system of power distribution with neutral grounded without resistance, and a nine thousand volt, three-phase, twenty-five cycle system between generating stations and substations, part solidly connected to ground, and part through a resistance of 0.5 ohm. Their circuits are partly overhead and partly underground. The writer closes his remarks with the following:

"Our investigation and experience with one system for five years, and another system for seven years, leads us to believe, that between operating with the neutral grounded or not grounded under our conditions, the grounding of the neutral is the better policy. As to whether or not any additional benefits would be secured by grounding the neutral through a resistance, we feel that our experience is still too limited."

The New York Edison Co. have a 6,600 volt three-phase, twenty-five cycle, ungrounded system. Their electrical engineer, Mr. Philip Torchio, gives in his discussion of the Rhodes and Clark papers a detailed analysis of all the high tension cable faults on this system for the period between November, 1898, and October, 1907. He says: "Furthermore, in every instance when we had a burn-out or disturbance of any kind, we fully investigated all attendant circumstances, and tried to figure out how the results might have been modified by having the neutral grounded. In no case of cable burn out did we find that the results might have been sensibly improved by the presence of the grounded neutral."

The arrangements of a company, taken to be the New York Central and Hudson River Railroad, are described by Mr. Carl Schwartz. This company is operating now one large power station at 11,000 volts in connection with the recent electrification of their New York terminals. They purpose using several resistances of 19 ohms each, one in the neutral lead of each generator.

Dr. C. P. Steinmetz sums up the matter, as it appears to him, in the following sentences:

1. The neutral of the three-phase system should not be grounded where grounding is not necessary.

2. The neutral should be grounded if the system cannot be operated safely when electrostatically unbalanced.

3. Whenever it is not necessary to have more than one ground on the system, it is desirable to ground the neutral at one place only.

4. Whenever it is not safe to ground without resistance, resistance should be used in the ground circuit.

A considerable number of companies operating distributing systems in America, and very many in Europe, have adopted the three-phase, four-wire method with neutral grounded. One of the chief objects of the grounding of the neutral is the protection of the service transformers scattered upon the high tension mains.

The experiences related above with a grounded neutral have been those upon systems operating high tension generators. Many of the long distance power transmissions in America ground the neutral point on the high tension side of the transformers. Among these may be mentioned several portions of the systems of the California Gas and Electric Corporation, the extensive system of the Telluride Power Co. in Utah, and that of the Guanajuato Power and Electric Co. in Mexico. Mr. F. G. Baum, in his article on "High Potential Long Distance Transmission and Control," at the International Electrical Congress of 1904, with reference to the system of the California Gas and Electric Corporation, says in part: "Our general practice is to generate at 2,300 volts and step up to the line voltage, the primary of the transformers being connected star with grounded neutral. I have come to believe the grounding of the neutral to have more advantages than disadvantages. We take advantage of the grounded neutral, and very often instal a single transformer in a substation, one side going to line, the other to ground, where the load is larger but does not warrant three transformers, we put in two, using two legs of the primary and open delta on the secondary. We are not bothered with any unbalancing of load at the power houses."

In discussing the October paper on this subject, Mr. Baum further says: "A number of years' experience with several large transmission systems operating at voltages from 10,000 to 75,000, both delta and star, demonstrate that where the systems are properly installed there is no more difficulty in operating one than the other. Most of the troubles of the early transmission systems came from lack of insulation; with improvement in insulation there disappeared nearly all the troubles variously ascribed to 'static charges,' 'lightning,' 'ground currents,' 'telephone and telegraphic interference,' etc."

"For very high voltage systems I see no reason for adopting anything but a star connection."

Dr. F. A. C. Perrine, in a paper on "American Practice in High Tension Line Construction," read before the International Electrical Congress at St. Louis in 1904, made the following statement: "In general it may be stated that up to 25,000 volts the delta connection is generally preferred, principally because with this connection a ground upon one line does not necessarily result in a short circuit, and, furthermore, the service is not necessarily interrupted in the case of the failure of a single transformer. At voltages higher than 25,000 volts the transformers for delta connection become more difficult to build and insulate. Furthermore, a single ground anywhere produces disturbances of a serious character, and in consequence the star connection with the grounded neutral is employed, advantage being taken of the fact that a grounded neutral aids in the distribution of unbalanced loads, and, furthermore, the rise of pressure which may occur from line discharge at the time of open-circuit or a short-circuit are not so likely to produce serious results.''

In conclusion it may be said that the subject, along with related matters with which it is involved, is so tremendous that justice cannot be done to it in any lecture or magazine article. The patient accumulation of the results of the experience of operating on systems will, with careful analysis, serve to guide the designers of transmission systems in the choice between grounding and not grounding, as dependent upon the special conditions of the case in hand.

PARTIAL BIBLIOGRAPHY OF LITERATURE DEALING WITH SUBJECTS RELATED TO THAT OF THE ''GROUNDED NEUTRAL.''

F. O. Blackwell, ''Y or △ Connection of Transformers.'' Trans. A.I.E.E., July 1, 1903.

C. P. Steinmetz, ''High Power Surges in Electric Distribution Systems of Great Magnitude.'' Trans. A.I.E.E., June 19, 1905.

P. H. Thomas, ''An Experimental Study of the Rise of Potential on Commercial Transmission Lines, Due to Static Disturbances, Caused by Switching, Grounding,'' etc. Trans. A.I.E.E., June 19, 1905. ''Grounded Neutrals with Series Resistances,'' *Electric Journal,* Vol. III., p. 484.

H. G. Stott, ''Incidents in the Operation of a Large Power Plant and Distribution System.'' *Electrical Journal,* Vol. II., p. 278.

C. W. Ricker, ''Experience with Grounded Neutral in High Tension Plant.'' *Electrical Journal,* Vol. III., p. 507.

R. P. Jackson, ''A Peculiar Static Trouble.'' *Electric Journal,* Vol. III., p. 646.

A. G. Grier, ''Circulating Currents in Three-Phase Generators.'' *Electrical Journal,* Vol. IV., p. 189.

C. F. Scott, '' The Grounded Neutral.'' *Electric Journal,* Vol. IV., p. 662.

G. N. Eastman, ''Harmonics in Three-Phase Circuits.'' *Electric Journal,* Vol. IV., p. 361. ''The Grounded Neutral on Three-Phase Alternating Current Systems.'' Nat. Elec. Lt. Assa., 1904.

G. N. Eastman, ''Protection and Control of Large High Tension Alternating Current Distributing Systems.'' Trans. Int. Elec. Congress, St. Louis, 1904, Vol. II., p. 518.

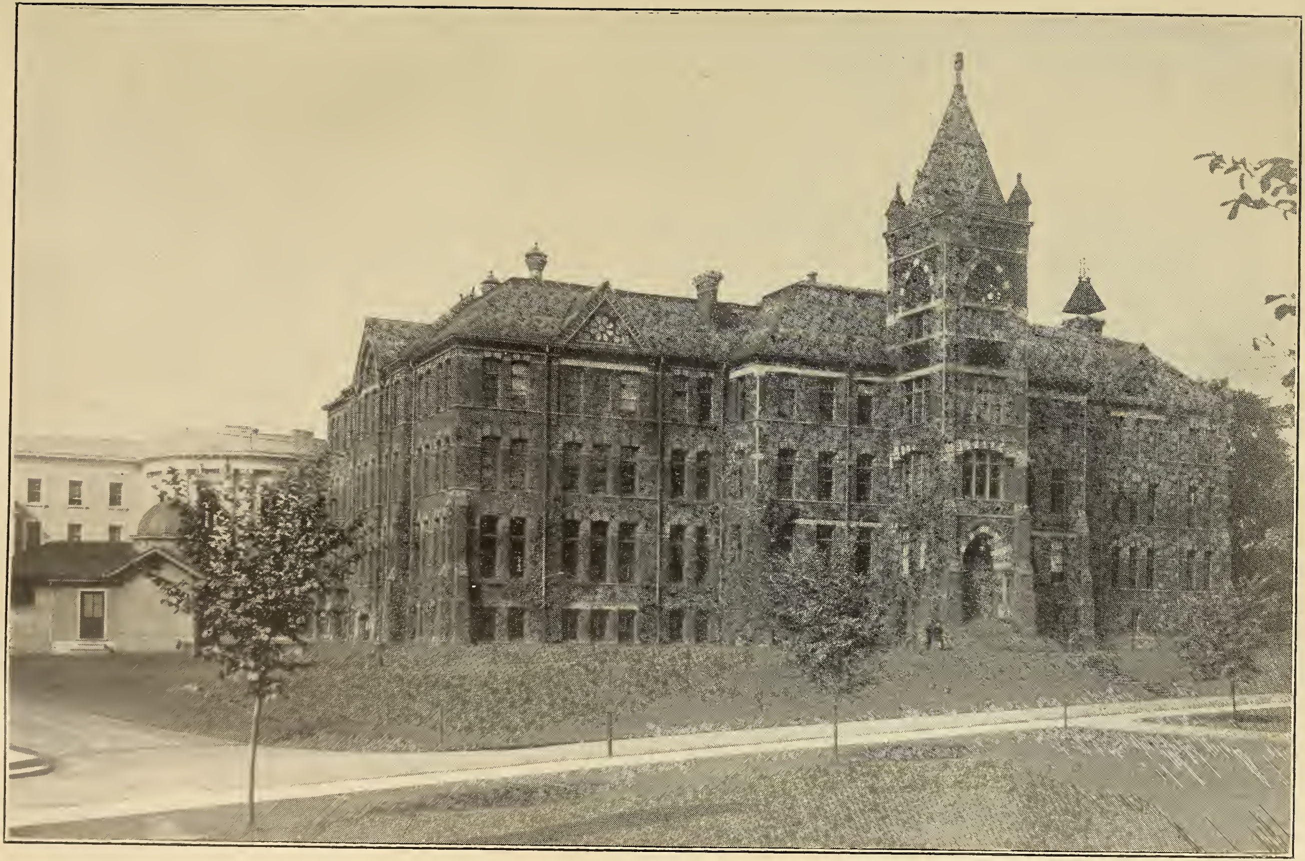
Humann, ''Annual Savings by Use of Grounded Neutral.'' *Elek. Zeit.,* May 5, 1904.

E. J. Berg, ''Line Constants and Abnormal Voltages and Currents in High Potential Transmissions.'' Trans. A.I.E.E., January 31, 1907.

P. M. Lincoln, ''Transposition and Relative Location of Power and Telephone Lines.'' Trans. A.I.E.E., March 27, 1903.

P. M. Lincoln, ''The Grounded Neutral, with and without Series Resistance in High Tension Systems.'' Trans. A.I.E.E., October 11, 1907.

G. I. Rhodes, ''Experience with a Grounded Neutral on the



ENGINEERING BUILDING, UNIVERSITY OF TORONTO

Supplement Applied Science, January, 1908

High Tension System of the Interborough Rapid Transit Co." Trans. A.I.E.E., October 11, 1907. "Neutral Currents of a Three-Phase Grounded System." *Electrical Journal,* Vol. IV., p. 382.

F. G. Clark, "The Grounded Neutral (Experience on the Distributing System of the Long Island Division of the Pennsylvania R.R.)" Trans. A.I.E.E., October 11, 1907. Discussion on papers read October 11, 1907, by Messrs. Junkersfeld, Torchio, Steinmetz, and others.

C. P. Steinmetz. Trans. A.I.E.E., 1901.
A. E. Kennelly. El. Wld. and Engr., 1901.
J. D. Nies. El. Wld. and Engr., 1902.
P. H. Thomas. Trans. A.I.E.E., 1902.
G. N. Eastman. Western Electrician, 1903.
David. Societe Int. des Electriciens, 1904.
Blonden. Societe Int. des Electriciens, 1905.
Brylinski. Societe Int. des Electriciens, 1905.
G. H. Parchell. Institution of Elec. Engrs., 1905-6.

Bibliography by Mr. Philip Torchio in discussion of Rhodes and Clark papers.

SOME NOTES ON MAINTENANCE OF WAY

G. HOGARTH, '09

BALLAST.

The ballast is a most important item in securing a good track and economy in maintenance and operation. The material should, if possible, be carefully selected, as it may have a decided effect on locomotive and car maintenance, as well as on the traffic. A dusty ballast will cause greatly increased wear on the journals and motion and on roads with extensive passenger traffic it is absolutely necessary to avoid dust and dirt by the use of good clean ballast.

The object of ballast is to distribute the load over the roadbed, to hold the ties in place horizontally and provide efficient drainage around and under them, so as to prevent freezing up in winter, to afford a means of keeping the ties truly up to the grade line, and to give elasticity to the roadbed. This is a statement of a perfect ballast and the value of the different kinds depends on the extent to which they fulfil these requirements.

This perfect ballast is never the most economical for all roads, as light traffic justifies something cheaper, but here the common error of using a very cheap ballast creeps in.

A railroad causes great discomfort to its passengers, and wear and tear on the journals of the cars and engines, where a little additional expenditure to provide a more suitable material would have made it a more pleasant road to ride on, and been much more economical to maintain.

The materials most commonly used are cinders, slag, gravel and broken stone, and in some cases, where these are hard to obtain, earth is used and called mud ballast.

Where the natural soil is gravelly and the water will drain through it quickly, it will make a fair roadbed for light traffic, but since this condition seldom, if ever, exists for a great distance, and since a heavy rain will spoil the results of weeks of patient surfacing of the track, it is seldom economical or satisfactory to use mud ballast if there is a gravel bed or other sources of ballast anywhere on the line of the road.

A liberal depth of ballast should always be allowed About 18″ below the tie is an excellent depth, but is very seldom used. Twelve inches should be a minimum depth, but very frequently this is cut down, and we find only 8″ to 12″ of ballast between the bottom of the tie and the upper surface of the roadbed.

CINDERS.

Cinders defined as the residue from the coal used in locomotives or other furnaces are only used as ballast after the road is in operation. They make a cheap and serviceable ballast, are easily handled with a shovel, prevent weeds growing, and being porous give excellent drainage. They are used extensively in yards and sidetracks on branch lines, where they will last for some time under light traffic, and are very useful in wet places, where the frost tends to heave the track. In some yards earth ballast is first used, and as the drainage is usually poor, a wet track results. The ties soon get loose and work up and down in the liquid mud. A good remedy for this is to dig out the wet spot, put in a good layer of cinders as ballast, and then lift the whole track several inches. For washouts cinders are frequently made use of, as several carloads, if necessary, can be quickly sent to the break in the track, and the damage repaired. Because of their good draining qualities cinders are preferable to gravel in yards, but as ballast on main line they are very objectionable, on account of the clouds of dust raised by passing trains in hot weather.

SLAG.

Furnace slag, or cinder, is extensively used on roads in the vicinity of blast furnaces and iron works. It is as durable as broken stone, and furnishes an excellent ballast, free from dust and perfect in drainage qualities. It is sometimes said that ties decay and spikes rust more rapidly in some kinds of slag ballast than in stone, but if properly drained the difference is slight. Slag gives excellent results; it keeps the track in good line and surface, and does not heave as much as gravel. It has been used by one large road for about twelve years, and has been very satisfactory and economical. That road arranged with the furnace company that the slag was to be poured from the pots down an incline 30 to 40 feet, when the slag cools rapidly, and has the appearance of broken china instead of the porous sponge-like appearance of slag handled in the ordinary way. It is also extensively used in England, where it is run from the furance on to a travelling belt, and suddenly cooled by water, which hardens it and breaks it up at the same time.

GRAVEL.

Gravel is the most common form of ballast that may be called good ballast. For light traffic, or on a busy main line, where a better but more expensive ballast is out of the question, or on a road where dust is not objectionable, it is most satisfactory and economical. Its good qualities are, it is easily worked, provides good drainage and keeps the track in good surface. Where the prevention of dust is desirable the gravel should be screened or washed. The screen used should have a ½″ mesh, so as to get rid of all dirt and the finest stones, but on account of the added expense it is seldom subjected to this treatment.

Gravel pits are not very common in Ontario, and where a good one is found near a railroad it is purchased, a steam shovel put in and the ballast sent wherever needed. The greater part of our railroad mileage is ballasted with gravel, and wherever used it is found satisfactory.

ROCK AND BROKEN STONE.

Rock or broken stone is in general the best material for ballast, as it meets all the requirements. The stone used should be durable enough to resist the disintegrating influences of the climate where it is used, hard enough to prevent pulverizing under the treatment to which it is subjected, and should break in angular pieces when crushed. The maximum size of pieces should pass through a screen having 2″ holes, but with regard to the minimum size, there is a variance of opinion. Some say the minimum size shall not pass through a screen having ¾″ holes, while others say that by having pieces that will pass through ¼″ holes the ballast sets quicker and requires less packing to make it firm. Rock ballast does not freeze solid, nor heave in cold weather; it can be worked in wet and dry weather alike; it becomes compact when in the track, has little or no dust, will stand hard tamping with a tamping bar; is one of the best ballasts known to shed water, and gives a longer life to the ties.

The best rocks for ballast are granite, trap and limestone, and the broken stone should be handled with forks, so as to avoid getting dirt and dust mixed up with it. This kind of ballast is more expensive than any other, but under heavy traffic will keep its surface better, and will require less work for maintenance than any other after the ties have once become thoroughly bedded.

The manner in which the ballast is distributed along the track is generally by means of specially constructed cars, which may have either side doors or centre doors. In the case of the side doors a large gang of shovellers, or a ballast plow, is necessary to clear the cars. If a ballast plow is used, it is put at one end of the train, and a steel cable is run from it over the cars to a winding engine at the other end. The plow is then slowly pulled over the cars and the ballast forced off. The plow is the same width as the inside of the cars, and is guided by either a ridge along the centre of the car or by the posts supporting the side doors. In the case of centre drop cars the doors are opened and the train slowly passes over the track. By this means the ballast is evenly distributed.

The cost of ballast in the track varies with the different roads. It depends on (1) first cost of material, as it comes to the road; (2) on the distance of the source of supply to the place where it is used and on the method of handling. The first cost of cinders or slag is frequently insignificant, a gravel pit may cost nothing except the price of a little additional land beyond the limits of the right of way. Stone will usually cost $1 or more per yard. The cost of handling per cubic yard will be small if a steam shovel is used, but hand shovelling will cost more. The cost of hauling depends on the distance hauled and also on the amount of traffic, for the work train must keep out of the way of the regular trains. The cost of broken stone ballast in the track is estimated at $1.25 per cub. yard, and gravel at about 45c. to 50c. per cubic yard.

The amount of ballast needed per mile is:

Single track, stone, 2,300 cub. yards; gravel, 1,900 cub. yards.
Double track, stone, 5,300 cub. yards; gravel, 4,100 cub. yards.

Thus the difference in cost between gravel and stone per mile of single track is $2,020, and per mile of double track, $4,780.

TIES.

In order that the rails may have a firm foundation to rest on, and also be held rigidly at a certain distance apart, some form of tie is necessary. There are many different forms of supports and ties, but the one familiar to us is the wooden tie.

The essentials for a good railroad tie are few compared to the essentials in wood for other purposes. These essentials are mainly durability, resistance to the cutting action of the rail, and ability to hold the spike firmly. All woods do not fulfil these requirements, as some are hard and some soft, so they differ in the main essentials of a good tie. There are many varieties that are found satisfactory, such as white and red oak, yellow pine, white and red cedar, beech, maple, spruce, hemlock and tamarack. The commonest kinds in use to-day are red and white oak and cedar. Cedar is common in Canada, but the oak ties are almost all imported.

The oak tie is mainly used on curves, and the cedar on tangents. The reason for this is that the outward thrust of the rail would soon loosen the spikes in a softer tie. It is also the best wood for ties, both for wear and durability combined, being very hard and slow to rot, and generally failing by decay rather than by wear. The cedar ties are good and durable, but their softness leads to cutting under the rails.

The life of a tie depends on its resistance to natural decay and its ability to resist the cutting and abrading action of the rail. On a main line the average life of a cedar tie is 7 to 8 years, while on a branch line the same tie will last 12 to 15 years. Red oak has a little longer life than cedar under the same conditions.

Almost every railroad has its standard size of ties, but the majority favor a tie 8′ or 8′ 6″ long, 6″ to 7″ thick, and 8″ to 9″ wide. For heavy traffic the length of the tie is sometimes 9′.

The spacing of ties varies from 14 to 18 per 30′ rail, depending on whether it is a main line, branch line or yard track.

In the maintenance of way account the cost of ties is quite an item, as thousands are required for renewals, and the price per tie is about 41c. for cedar and 58c. for creosoted oak.

Because of the rather short life of a tie in the track many preservative processes have been tried, and several of them add considerably to the life of the tie.

The different processes are creosoting, zinc chloride, zinc tannin and Wellhouse. In the creosoting process the ties are first placed in a large iron cylinder and the air exhausted, thus drawing out the sap. Live steam is then turned in for about 20 minutes, when it is shut off and a vacuum again created to open the pores of the wood. This lasts about 20 minutes and live steam is again turned in, the pressure raised to 30 lbs. per square inch, and maintained six to eight hours. The steam is then blown off and a vacuum created, after which hot creosote oil is run in, the pressure raised to from 80 to 100 lbs. per square inch, and maintained from one to two hours, depending on the size and kind of the timber.

The oil most commonly used is dead oil of coal tar. It is obtained by the distillation of coal tar, and its preservative value lies in the fact that it contains napthaline, which melts about 175° F., so that after being liquified by the heat of the steam it penetrates the tie, becomes solidified and is permanently fixed. The ties subjected to the process should be well seasoned and dry, as then they will take up a great deal more of the oil which, when solidified by exposure, no moisture in the air or ground can succeed in removing.

The mechanical part of the other processes is much the same, but as their names indicate a different preservative is used. In each process a vacuum is first obtained, and then in the zinc chloride treatment zinc chloride is forced into the ties. With the zinc tannin process first zinc chloride, then a weak solution of tannic acid, and after that a 1% solution of glue is injected. The Wellhouse process is the same as the zinc tannin, but the zinc chloride and glue are mixed together and injected at the same time, while the tannic acid is injected a short time afterwards.

The preservative processes have been given a great deal of attention during the last few years, as the forests are rapidly becoming depleted and suitable wood is becoming scarcer every day, so that what wood is now available should be made to last as long as possible.

RAILS.

The development of the modern rail may be briefly summarized as follows: Flat cast-iron rails or plates, about three feet long, were first used, and these were succeeded by cast-iron rails of L section, laid with the horizontal flange outward, the ends of the rails resting on stone blocks. On these angle rail tracks flangeless wheels were used. About 1789 edge rails were introduced, the wheel running on the upper edge of the rail and being guided by a flange on the wheel. The first were of cast-iron, fish bellied, in short lengths of about 3′, with the ends resting on stone blocks, or in cast-iron chairs on these blocks. Later on the rails were made of wrought iron in 15′ to 18′ lengths, fish bellied, between supports about 3′ apart. These rails were rolled, the rail and rolls being invented by John Birkinshaw, of England, in 1820. The bridge rail, designed in 1834, was used on some of the early railways. The pear section was an approach to the present form, but was very defective on account of the difficulty of designing a good form of joint.

The present flange, or T rail section was invented in 1830 by Colonel Robert L. Stevens, Chief Engineer of the Camden and Amboy Railway, and the first order was placed in England by him for this road. Various forms of compound rails have been designed, particularly in the early days of railways, to enable the wearing part of the rail to be renewed, but the majority proved failures, owing either to faulty connections or too great complications. The idea has, however, been revived in connection with modern heavy track, and in 1894 the compound rail, shown in the figure, was suggested.

Up to fifteen years ago there was an almost entire lack of uni-

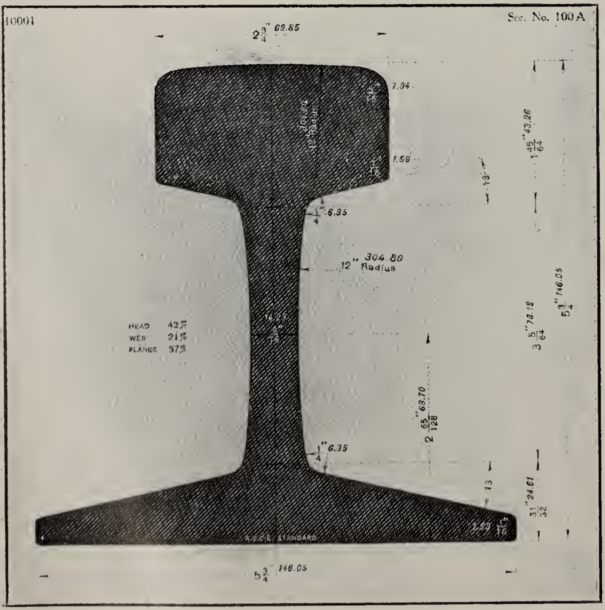


Fig. 1. A.S.C.E. Standard 100-Pound Rail

formity in rail design, and the mills had to carry enormous stocks of rolls for the innumerable forms of section. Many of these sections were practically identical, but had minute variations in certain dimensions, as the result of the whim of the designer, or his being unaware of the existence of a practically similar section. Each engineer had his own ideas as to rail design; and desired to have his own special form of section on his own line.

In 1893 the American Society of Civil Engineers, after a very thorough investigation extending over a number of years, having obtained the opinions of the best experts of the country, adopted a series of sections, which have been used by American and Canadian railways.

Instead of having the rail sections for various weights to be geometrically, similar figures, certain dimensions are made constant regardless of the weight. It was decided that the metal should be distributed through the section in the proportions of head 42%, web 21%, and flange 37%. The top of the head should have a radius of 12", the top corner radius should be 5-16", the lower corner radius of head should be 1-16", the corners of the flanges 1-16" radius, side radius of web 12", top and bottom radius of web corners ¼", and the angles with the horizontal of the under side of the head and the top of the flange 13°.

The sides of the head are vertical. The height of the rail and the width of the base are always made equal to each other.

A standard composition of rails of 90 lbs. per yard and upwards is carbon .5 to .6.

Phosphorus, not over..................	.1
Silicon, not over......................	.2
Manganese	.8 to 1.10

The standard lengths are 30 and 33 feet, but 10% of the order must be accepted in short lengths varying by even feet down to 24'. Also a variation of ¼" from the length specified is allowed.

Rails break far more frequently in some places than in others and the commonest place is in the head where they split parallel with the length of the rail. Then the head may crack across, the crack will extend down to the top of the web and then run back along the web so that perhaps 4' or 5', or the whole head may come off. Then again the side of the head may break off.

These breaks occurring very frequently in the head and the under side of the head naturally lead us to look there for the defect. Such breakages were not common in the old Barrow rails and this may be accounted for by the fact that the radius of the fillet between the web and the head was greater in the Barrow than in the modern rail.

Rails are liable to break on straight track as well as on curves and at all times of the year, but there is a greater number of failures in the spring, when the frost is coming out than at any other time of the year. In some cases the rail breaks straight off or nearly so. These breaks occur both on the ties and between the ties and are probably due to the heavy blow of a flat wheel striking a weak spot on the rail.

The minimum weight economical in ordinary service is 65 lbs., though many roads have used lighter rails even under considerable traffic. In such cases, however, the diminished life of the ties and rails and the increased cost of material and labor for maintenance and renewals as well as the occasional sums involved in repairs and damage suits after wrecks, more than balance the cost of rails of suitable weight.

For ordinary freight and passenger traffic on roads with easy curves and grades the weight should be 70 to 80 lbs., while for extra heavy freight or fast passenger trains or on lines with sharp curves and steep grades the rails should weigh from 80 lbs. upward.

To illustrate how heavy rails and stiffness assist the tractive force of engines the experiment of hauling a train load of 378 tons at a speed of 55 miles per hour over 65 and 80-lb. rails showed that it took 820 horse power on the 65-lb. rails and 720 horse power on the 80-lb., while it was estimated 620 h.p. would have been required on 105-lb. rails.

The cost of rails to-day is about $30.50 and 18 cents inspection, making a total of $30.68 per ton. At that price one mile of 100-lb. rails would cost $4,821.

SUPERELEVATION.

As a rule the outer rail on main line curves is elevated a certain distance above the inner rail. The elevation depends on the degree of the curve, on the speed at which trains pass around it and the relation of the curve to the grades on either side of it.

A common practice is to elevate ½″ to 1¼″ per degree. The reason for such a range of elevations is apparent when we consider a double track road on, say, a 0.5% grade. The elevation of the curve of the ascending track should not be as much as the descending track and in case of a curve upon the summit the amount of elevation should be less than that of the same degree of curvature on a comparatively level track. Again a curve at the foot of a grade should have more elevation than the same degree of curve with no grades near it. This, of course, simply means that the curve must be elevated with regard to the speed of the trains and also with respect to the radius.

Satisfactory and easy as this may appear to be, it becomes a very complicated problem in the case of a single track road having a continual rise in one direction. Then there are four widely different speeds to consider. The speed of freight and passenger trains going in the direction of the rise and the same trains going in the opposite direction.

It is evidently impossible to elevate a curve to suit all four speeds and the practical way it is done is to elevate 1⅛″ for each degree of curvature, the elevation never to exceed 7″ and then closely watch the track to see the effect. *The manner in which the rails wear and act is the surest indication of having a practically* *correct elevation.* If the low rail wears badly and tends to spread the elevation is too great, while if the high or outside rail becomes worn and shoved out of place the elevation is insufficient. It is then left to the track foreman to find by experiment the elevation at which both rails wear evenly and there is no evidence that one rail tends to spread more than the other.

SWITCHES AND FROGS.

In order that a train may pass from one track to another a switch is necessary. The first switches used were called stub switches, but as they were the cause of many derailments and are not suitable for main line the railroads have adopted the split or point switch. This switch consists essentially of two point rails by one of which the flanges of the wheels are diverted on to the turnout or switch and a contrivance called a frog having channels on its upper surface through which the flanges of the wheels pass.

The parts of switch that have to withstand the greatest amount of wear are the points and the frog. In the case of the points the wear is caused by the pressure of the wheel flange and this tends to squeeze the metal and distort the point. A hard blow will somtimes break off a piece of the point rail.

For these reasons manganese steel points are coming into favor for switches that are constantly in use on main line or yard tracks where the volume of traffic wears out Bessemer steel points in a few months. Because of their cost manganese points are not economical except under conditions where by their toughness and great wearing qualities they outlast many pairs of ordinary steel points.

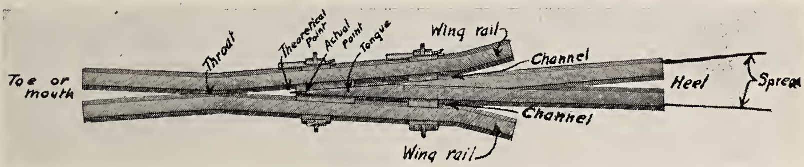


Fig. 2

Frogs are classified according to the spread of the rails composing the frog. A spread of one foot in eight feet is called a No. 8 frog, similarly a spread of one foot in twenty feet is called a No. 20 frog. The common numbers in use run from 4 or 5 for a very sharp turnout to a 12, 14 or 20 for a main line junction.

Frogs were originally made of cast iron but the present universal practice is to build the frog up of pieces of rails which are cut and bent as required. These pieces of rail (usually four) are sometimes assembled by rivetting to a flat plate but this method is now but little used. The present practice is now chiefly divided between bolted and keyed frogs. In each case the space between the rails except a sufficient flangeway is filled with a cast iron filler and the whole assemblage of parts is suitably bolted or clamped together.

The distance from the point of the frog to the point of the switch or the lead, as it is called, depends on the number of the frog. The theoretical lead (the formula for which is twice the gauge multiplied by the number of the frog is never used as it does not give an even curve on the turnout is very hard to line accurately, and in the case of a long lead all the curve will be found on the first rail or two following the switch point. For those reasons the shortened or practical lead is used. This lead may be calculated as follows for No. 6, 7 or 8 frogs nine times the number of the frog gives the shortened lead in feet, for 9 and 10 frogs eight and a half times the number of the frog and for frogs above 10, eight times the number of the frog. For example, a No. 9 shortened lead should be $9 \times 8\frac{1}{2} = 76\frac{1}{2}$ feet, but in order to save cutting rails even this lead may be varied several feet.

The two kinds of frogs in use are rigid and spring rail. The rigid frog is provided with two channel ways or flange spaces through which the flanges of the wheels pass. Since the wheel tread is always wider than the rail, the wing rails will support the wheel not only across the space cut out by the channels, but also until the tread has passed the point of the frog and can obtain a broad area of contact on the tongue of the frog. This is the theoretical idea, but it is very imperfectly realized. The wing rails are sometimes subjected to excessive wear owing to the hollow or worn treads of wheels.

The break that the channels make in the continuity of the rail becomes extremely objectionable at high speeds, being mutually destructive to the rolling stock and the frog. This led to the introduction of a frog having one wing rail operated by a strong spring so that the wing rail is held close up to the tongue and thus gives a practically continuous rail for the main track. The spring rail only comes into operation when a car goes on the siding and when this happens the flange of the wheel presses back the spring rail thus making the necessary channel. The Eureka spring rail frog has given satisfaction wherever used.

Manganese steel frogs first came into use in 1901 and since that year they have come to take a place of their own in track work. They are most economical for terminals where the constant passing of trains soon renders a Bessemer steel frog useless, but because of their high first cost they are only used in places where an ordinary frog lasts but a few months.

In these days of many railroads crossings of one road by another are frequent. A diamond is put in at the crossing. This is usually built up of parts of rails, but with modern high-speed and heavy trains a rail diamond, no matter how well it is reinforced, must be constantly looked after and repaired. If the tracks are in constant use a Bessemer steel diamond is soon hammered out of shape by the pounding it receives. For this reason manganese steel castings are being used for the wearing parts of diamonds. This metal is so very tough and hard that a file or chisel will not make a mark on it and in order to smooth it off at all it must be ground. It is practically indestructible and will last a very long time without showing any signs of wear beyond a very white polished surface.

ACTION OF THE ROADBED.

One of the many things to be considered in constructing a railroad is the drainage, as it frequently causes a large outlay after the road is in operation. Where the road is on an embankment the drainage problem does not present itself but if a long deep cut is introduced then the engineer must carefully look after the side ditches and see that they are made of sufficient size and depth to carry off all water and properly drain the track.

Each railroad has its standard width of roadbed and side ditches but as the material through which the cut is run is very frequently clay they are almost certain to have a wet spongy track unless carefulness is exercised both in constructing the side ditches and in placing sufficient ballast under the ties. It has been observed that in a cut where the roadbed is of clay and where perhaps there are only 10 to 12 inches of ballast between the under surface of the tie and the top of the roadbed a swelling of the clay will occur between the ties.

This is caused by there not being sufficient ballast under the tie to distribute the weight on the tie evenly on the roadbed. As a result the ties press nearly directly on the soft wet clay and thrusting down into it cause it to swell up in a ridge between them. The distortion of the roadbed is frequently noticeable, as the clay also squeezes out laterally and partially fills the side ditches.

In the case of a freight yard constructed a few years ago insufficient ballast was allowed, the drainage was rather poor, and to-day the yard foreman spends the greater portion of his time watching his men jacking the ties up out of the mud and putting cinders under them.

Thus a wet, spongy, unsatisfactory track that is costly to maintain is the direct result of being economical of ballast and careless of drainage.

In 1890, after three years of experimenting it was found that a swelling of the clay between the ties will not occur even under the most favorable conditions when the height of the under surface of the tie above the roadbed is eight inches more than the clear distance between the ties. This shows that in any locality where the surrounding conditions indicate that a wet track is to be expected, a liberal supply of ballast should be placed under the ties.

However, practical experience shows these experiments were in error as the above procedure does not always result satisfactory. The track is still saturated with water and until this is drained away the ballast will sink down into the clay and the clay will ooze up.

The only remedy that gives lasting satisfactory results is to thoroughly drain the cut with tile drains placed in the ditches.

TIE PLATES

One of the most important and practical of modern improvements in railway track has been effected by the wide introduction of metal tie plates which are placed between the rail and the tie and which involve only a small first cost but effect a most decided economy in ties and in track work. Their cheapness combined with their undoubted advantages in efficiency and economy has led to their adoption on hundreds of miles of track as it is recognized that they not only increase the life of soft and cheap, though durable, untreated ties but effect a direct economy in renewals and maintenance of way; while at the same time they add to the permanence and security of the track by giving a uniform and durable bearing to the rails and lessening the disturbance of the track for tie renewals. They are especially advantageous for soft ties under heavy traffic. The life of a soft-wood tie is very much reduced by rail cutting and by not offering sufficient resistance to the moving of the spike thus causing rot around the spike holes and frequently requiring renewal before decay has set in.

Tie plates cause the spikes on both sides of the rail to act equally to resist lateral pressure in either direction as the plate ties the two spikes together. The spikes clasp the base of the rail tightly, thus preventing it moving and so reduce the wear or necking of the spikes by the rail.

It is a very important feature that the spike holes should be so punched that the spikes will fit closely to the base of the rail. Otherwise a lateral motion of the rail will be permitted which will defeat one of the main objects of the use of the plate. A standard distance between the holes is 1-16″ less than the width of the rail base.

It has been practically demonstrated that the rail cutting is not due to the mere pressure of the rail on the tie even with a maximum load on the rail but is due to the impact resulting from vibration and to the longtitudinal working of the rail. It has been proved that this rail cutting is practically prevented by the use of tie plates.

On steep grades they prevent the increased cutting of the ties due to sand from the engines getting under the rail and abrading the wood. Tie plates also act as effective rail braces for the outside rail of curves.

The cost of tie plates is very small compared with the value of the added life of the tie, the large reduction in the work of track maintenance and the smoother running on the better track which is obtained. It has been estimated that by the use of tie plates the life of hardwood ties is increased from one to three years and the life of softwood ties is increased three to six years. From the very nature of the case the value of tie plates is greater when they are used to protect soft ties.

Tie plates may be used with special advantage as follows: In terminal yards, on bridges, on sharp curves, on the ties in the switch lead, at rail joints on tangents and on a busy main line where the heavy traffic causes the ties to be cut into by the rails before decay sets in.

Many forms of tie plates have been introduced. The first plates used were flat pieces of boiler iron with holes punched for spikes. The next was a flat-bottomed plate with a shoulder on top. Both of these had many disadvantages. It was impossible to keep them tight, hence they caused wear and decay and also jumped and rattled under passing trains.

Besides the plates tended to bend and buckle, while if made sufficiently thick to resist bending, the plate was clumsy and expensive. The question then was how to secure a permanent connection between the plate and the tie and this appears to have been efficiently attained by making a plate with longtitudinal ribs or flanges which sink into the fibres of the weed from ¾″ to 1⅜″ and are tightly held by them while the size of the flanges is not such as to crush or split the wood. These flanges also serve to stiffen the plate and enable a thin plate to be used without bucking under heavy loads. The plate with longitudinal flanges has proved by length of service that it has a secure grip on the tie and protects the wood, while the objection that it causes the tie to split and thus hasten decay has not been sustained.

It is claimed that the tie plate with four spurs projecting into the tie across the grain has a grip equal to that of four good spikes and that the spurs require a constantly increasing lateral load to move even when once started. This, of course, means that when once seated the plate is absolutely fixed but the same may be said of the longitudinal flange plate.

The best forms of tie plates are of comparatively recent design and experience with them is still insufficient to determine beyond all question which design is best.

A very important detail in the process of setting the tie plates on the ties is that the flanges or teeth should penetrate the tie as far as desired when the plates are first put in position. It requires considerable force to press the teeth into the tie. In some cases trackmen have depended on the easy process of waiting for passing trains to force the teeth down. Until the teeth are down the spikes cannot be driven home and this apparently cheap and easy way results in loose spikes and rails. If the trackmen neglect even temporarily to tighten these spikes it will be impossible to make them tight ultimately.

The plates are generally pounded into place with a 10-16 pound sledge hammer. A very good method was adopted once when a pile driver was at hand. The bridge ties with the tie plates accurately set to gauge on them were placed under the hammer and the plate forced home by a 2′ or 3′ fall of the hammer.

One of the first questions that you may have in mind is "Why is the width of the track between rail heads or the gauge, as it is called, 4′ 8½″? Why not 4′, 5′ or 6′?"

It is not known what, if any, principle governed the determination in the first instance of the distance between the rails of 4′ 8½″. It was adopted by the roads from the collieries in the north of England and believed to have arisen from the colliery wagons in use on common roads, having an outside width of axle of 5′, for, as the tramroads had the flange on the outer edge of the rail these ordinary wagons could be used on them and when the flange rail was replaced by the edge rail the same width of track was continued but measured from the inner edge of the rail resulted in the 4′ 8½″ gauge. Another reason given by an authority is that the tramways were 5′ wide, including the rails, and as the later edge rails were 1¾″ wide they practically determined the gauge at 4′ 8½″ as soon as they were introduced. Mr. Stephenson engaged in these collieries, was selected to build the Liverpool and Manchester road, and seeing no reason to change the gauge with which he was familiar, it was adopted there. As that gauge proved satisfactory on the Liverpool and Manchester it was used by some other roads as they were built. The necessity of having a standard gauge no doubt arose out of the fact that with any other gauge the interchange of loaded cars was an impossibility. As traffic increased and one road having a certain gauge received freight to be delivered on another road having a different one it was evident that a common gauge was necessary. However, the majority of railroad companies had a gauge of 4′ 8½″ and as they were unwilling to change it, 4′ 8½″ was decided on as the standard.

NOTES ON THE CAUSE AND PREVENTION OF THE CORROSION OF IRON

F. N. SPELLER, B.A. Sc.

The corrosion of iron has been the object of investigation and experiment for many years, but not until recently has the subject been dealt with on broad scientific lines with the object of determining the underlying causes and scientific methods for prevention of corrosion. The need of careful practical research along this line is evident when we consider the interests at stake and the increasing destructive nature of modern corrosive agencies.

Theories of Corrosion.—To explain the underlying causes of corrosion, any theory must account for the fact that iron will remain bright indefinitely in water free from air, and is equally well preserved in air free from moisture. Commercial wrought iron and steel are here considered together as "iron," a clear distinction being in fact difficult to make.

For many years the carbonic acid theory was considered satisfactory. Two reactions are said to occur. In the first carbonic acid is an essential agency.

$$(1)\ 4Fe + 4H_2O + 4CO_2 = 4FeCO_3 + 4H_2$$

$$(2)\ 4FeCO_3 + 6H_2O + O_2 = 2Fe_2(OH)_6 + 4CO_2$$

There seems to be good ground for the belief that the presence of CO_2 in solution accelerates corrosion considerably. However, while not overlooking the effect of CO_2 (which requires further investigation), it was conclusively shown by Whitney in 1903 and quite recently confirmed by A. S. Cushman and W. H. Walker and others, that iron will go into solution in water entirely free from carbonic acid. The latter investigators, on the suggestion of Dr. Cushman have worked out a method for showing the solution of iron by means of a combination of two delicate indicators (called Ferroxyl by Dr. Cushman). If we add a few drops of phenolphthalein to distilled water, render neutral, with 1/100 normal caustic soda, and then run in enough of a fresh solution of ferricyanide of potassium to turn the water faintly yellow; on dropping in a piece of bright iron, blue areas will appear after a few minutes where ions of iron are entering the solution at the positive pole, while pink areas due to the presence of hydroxyl indicate the negative pole where hydrogen ions are leaving the solution, thus showing, as claimed by Whitney, that the initial corrosion of iron is an electro chemical phenomena.

The reaction is analogous to what happens when we immerse a piece of iron in sulphate of copper, hydrogen occupying a position between iron and copper in the electrochemical series. The solution pressure of the iron will force some of the metal into solution, a

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proportional amount of copper being plated out on the surface of the iron. In the corrosion of iron, hydrogen is plated out at the cathode, the hydroxyl liberated being indicated by the pink coloration with phenolphthalein. In experiments which we have made on solution of iron in air free water, it was found that after the concentration of iron in solution reaches a certain small amount (about 1 part in 5 or 10 million) the reaction practically ceases, due to polarization at the cathode, and by virtue of the back pressure of the iron already in solution as ferrous hydrate.* A secondary action now takes place in corrosion if a small amount of oxygen is present, whereby, as Prof. Walker has experimentally proven, the cathode is depolarized. The ferrous hydroxide is at the same time changed to ferric hydroxide, which is thrown out of solution as "rust." In this way the electrolytic theory accounts for the phenomenon we are all familiar with in every day life.

Now let us go back to the ferroxyl tests and learn, if possible, the origin of this difference of potential. It was at first assumed that the blue and pink areas indicated irregularities or lack of homogeneity in the metal itself. In order to ascertain the value of this polarity indicator as a means of detecting irregular distribution of the constituents in commercial iron, polished sections of plates were examined,the centre of the sample being from the central segregated portion of the ingot and the surface portion corresponding to the outer skin of the ingot, giving a comparatively wide difference in composition between spots on the same section less than 1/4″ apart when the sample is taken from the most segregated portion of the ingot. The sides of these samples were carefully covered with cotton soaked in shellac, which was allowed to harden to prevent scale or oxide from influencing the results, as a number of trials without this precaution showed the oxidized sides to be invariable cathode to the clean surface of the section. With this precaution it was found impossible to get the same configuration of the surface under ferroxyl twice, and no consistent effect was manifested between the segregated and purer portions adjoining, except in a few cases, where there was excessive segregation, the central portion then showed a tendency to go into solution, while the outside portion became cathodic. The polarity, as indicated in pink at the cathode and blue at the anode, gradually changes and reverses itself curiously, causing corrosion to progress uniformly, provided no influence is present to hold the polarity in one direction continuously. Here we have a probable explanation of pitting.

In 1904 the writer made an extensive investigation of the influence of oxidation of the surface on the polarity of two pieces of steel, and was struck by the large difference in potential (as much as 2/10 or 3/10 of a volt) found between clean iron and mill-scale. Ordinary rust or other substances electro negative to iron adhering to the surface will produce the same effect to a lesser degree. Take two clean iron rods connected by copper wires to the calibrating coil of an ordinary volt meter and immerse in salt water, a slight difference in potential will usually be shown. Now without disconnecting the wires, take one of these rods out into the air for a few seconds and replace it—a strong deflection amounting to, perhaps, 50 milli volts will be indicated with the electrode which was aerated as cathode. By replacing this rod and removing the other from solution for an equal length of time or perhaps a few seconds longer and replacing in the water again the current will be found to have reversed. With such controlling differences in potential, due to accidental irregularities in oxidation of the surface of iron and steel, the slight variation caused by such lack of homogeneity in composition as may occur on the surface of the average steel or iron plate, probably plays a minor part. This is not said to excuse poor work, for there is no doubt that carelessly made iron or steel shows up badly under corrosion, but many good pieces have pitted through for other causes than irregular composition, and according to our experience this is more often the case. When we were going through the laboratory stages of experimental work on corrosion, in one case pieces of the same tubes were immersed in aerated water, one being cleaned free from scale and the other in its natural state. The latter pitted badly, while the clean sample corroded uniformly.

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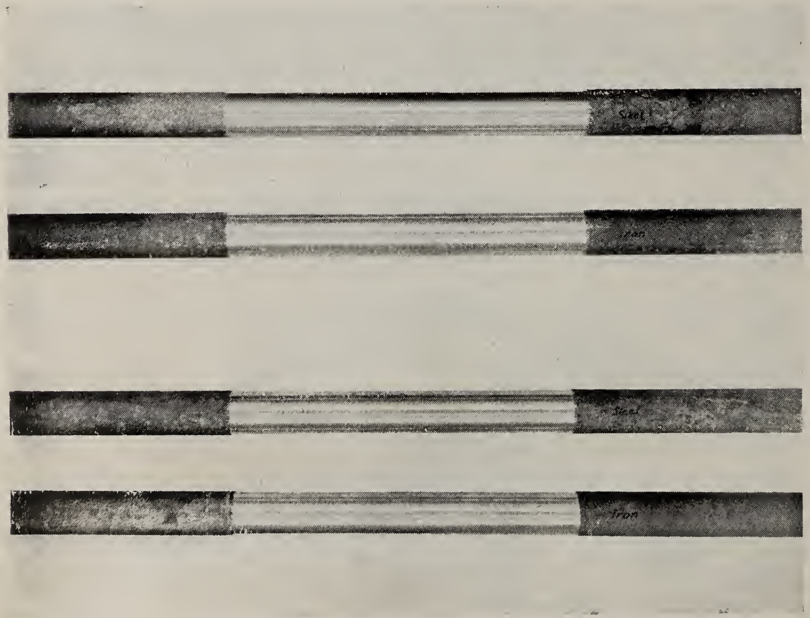
* We have measured the effect of ferrous sulphate in solution in the pickle baths used in the galvanizing works and found 40 per cent. ferrous sulphate to reduce the rate of solution of iron 100 per cent. in solutions where the free acid was maintained constant at 4, 5 or 6 per cent.

The rate of corrosion evidently depends more on the oxygen available than on any other factor, and whether the corrosion proceeds uniformly or is concentrated in pits, seems to depend more on the irregular distribution of foreign impurities in contact with the surface rather than on segregated spots of manganese or other elements which we find combined with steel. In some cases irregular density or flaws may contribute to localize corrosion; this will be referred to under a later head.

Does Wrought Iron or Steel Offer the Greater Resistance to Corrosion.—There is not space to discuss this phase of the subject in detail, but we can testify that so far as pipe and tube steel is concerned (and our investigations have been along this line entirely) the general impression which has prevailed as to the superior rust-resisting quality of wrought iron seems to be far astray from the truth. Theoretically there is no valid reason to expect one material to last longer than the other, and many laboratory tests show no material difference. Service tests of pipe and tubes, which have been conducted with special care as to equality of conditions, sustain this conclusion. For example, records of tests started nearly two years ago on a dozen railroads, at different parts of the country, show welded steel tubes to be equal and even superior to charcoal iron. It should be understood that this tube is made of soft steel which receives special attention as to uniformity and manipulation, it having been found that thorough working of the steel, while at the proper temperature, has much to do with its life. The conditions in a mill making pipe and tube steel exclusively are ideal so far as uniformity is concerned, in fact a high standard of material must be maintained if a satisfactory percentage of the steel made is to pass successfully through the ordeal at the welding furnaces.

Some have thought that the higher manganese would lessen the resisting power of steel compared with iron. When thoroughly mixed by a proper ladle reaction there can surely be no reason to suppose that a moderate manganese content is harmful; the ferroxyl test (the most delicate devised) does not show that steel carrying .30% manganese is affected perceptibly different from that made with .10% manganese. As to the uniformity obtainable in steel, we recently made a test by taking a sample from the last of the steel out of the ladle. Comparing the analysis of this with the regular ladle test: the maximum difference in manganese in 150 heats was found to be .05%, but in the majority of cases amounted to only .01 or .02%.

One example of a number of corrosion tests now under way might be cited. The question of relative durability of iron and steel condenser pipe having come up, we arranged 20 lengths of 2″ pipe alternately iron and steel in two racks and kept water dropping over them continuously in a warm place. The attached photograph shows the condition of four of these pipes, iron and steel, after 15 months, the centre portion having been turned down in a lathe below the deepest pit. No difference could be seen at this time. Many more tests under special conditions of service might be cited, but it is more satisfactory where the consumer is sufficiently interested to test the matter out under the conditions as you have them, bearing in mind that apparently slight changes in environment will greatly



Comparative Corrosion of Steel and Iron (Upper Steel) alter the results, hence the samples should be carefully placed so as to insure equality of conditions.

Results of a service test, conducted by Mr. T. N. Thomson, Sanitary Engineer at the International Correspondence Schools, Scranton, Pa. (American Society of Heating and Ventilating Engineers Annual Meeting, January 19th, 1908), show, in a hot water pipe line, consisting of alternate pieces of iron and steel that the steel corroded more uniformly and had decidedly the longer life. This investigator also throws some light on the cause for some of the aforementioned feeling which has caused many to continue to specify wrought iron when soft steel could be used to better advantage. It was found in the course of investigation among engineers, contractors, architects and steam fitters, that many were unable to distinguish between iron and steel, the presumption being that if the metal stood up well it was the traditional wrought iron, but if, on the other hand, it pitted badly no investigation was necessary, it being safe to conclude that the pipe was steel. This prejudice, or lack of knowledge of the materials and properties of welded pipe, is now less commonly met with.

PROTECTION FROM CORROSION.—The obligations of the iron or steel manufacturer are to produce a metal as homogeneous in composition as possible with a uniformly close texture developed to the best that is in it by proper treatment according to requirements. Such a metal will, of course, still rust, but with a greater uniformity than one made only with regard for the shape it is to take. Taking the electrolytic theory as our guide, there are evidently two general methods of protection, viz., making the iron insoluble, or as the electro-chemist might say, preventing the hydrogen from plating out of solution, or by protecting the surface from oxygen.

Iron in the passive state will not go into solution. This state is brought about by various agencies, for example, the action of concentrated nitric acid or chromic acid, an electric current with the piece to be passified as anode, or by chromates, ferricyanide of potassium, and other salts; potassium bichromate is probably the cheapest of these, a piece of bright iron immersed in a concentrated solution of this salt for several hours and then well washed in water will not corrode in moist air or water for some time. The protection is, however, not permanent, and is destroyed by heating to the boiling point of water.

NOTE—Passivity is explained by Dr. Cushman as due to retention of oxygen on the surface of the metal; other investigators believe that electric currents have much to do with it. The phenomena can be produced by an electric current, and the iron actified again by passing a current in the reverse direction with the passive iron as cathode. Is it not possible that the negative areas on the surface of a bright piece of iron which give a pink coloration with ferroxyl are due to passivity of the metal at these points brought about perhaps by different concentrations of oxygen on the surface of the metals?

We have frequently noted that where the polarity was changing under ferroxyl, the anodic areas were not strictly bright but appeared as though a film of oxide was forming on the surface, gradually making the anode less positive and finally reversing the direction of the current.

We can easily see how the reversal of polarity is accelerated if we assume that the cathodic areas are originally slightly passive, for they will soon be actified in contact with positive or active iron according to experiment by H. L. Heathcote.

(Soc. of Chem. Ind. Aug. 31, 1907.)

By immersing iron in a weak solution of bichromate of potassium (1 lb. in 1,500 gals. of pure water), Dr. Cushman has observed that the metal remains bright indefinitely. In order to determine whether the protecting influence could be relied upon at higher temperatures, we have kept weighed pieces of bright iron in a solution of 1 part to 1,500 of distilled water for four months at 95 degrees in a flask open to the air, but loosely covered with a simple condensing apparatus. At the end of this time the pieces were apparently unaffected, and curiously in every case, increased in weight slightly. It would seem that this treatment of the water might give good results in certain cases, for example, in boilers or steam-heating plants.

The treatment of water with alkalies also comes under this class of protection, the iron being prevented from going into solution in virtue of the concentration of hydroxyl ions.

Under the second method of protection we may class protective coatings, such as the various paints and oils, or where the iron is submerged we may remove oxygen and other corrosive matter from the water which comes in contact with the exposed surface.

In discussing the latest conception of the process of corrosion we have distinguished between two distinct operations, firstly, in solution of a very small quantity of iron, so slight as to be of no practical concern in itself, especially as the reaction soon comes to a stop unless oxygen is available, in which case we have a secondary reaction by which continuous corrosion is made possible.

For the protection of boilers, the air may be removed by heating the water in a vessel open to the atmosphere, as in the case of one class of feed water heaters, whereby the greater portion is driven out; corrosive gases left in the water after treating, can be removed by contact with a large surface of clean iron turnings or borings. A small amount of iron goes into solution, and the ferrous hydroxide thus formed takes up oxygen from the water, thus the boiler is protected at the expense of waste iron, which can be cheaply renewed from time to time as required. It is a common experience to find the portion of a boiler or heater nearest to the feed water entrance corroded while the rest of the boiler is unattacked. The same thing is seen in hot water heating systems, which very rarely, if ever, give trouble through corrosion, so long as the same water is used over and over in the system, but if hot water is drawn from the pipes for washing or other use and cold water fed in, corrosion ensues, the life of the system depending on the amount of cold water put in. Under these latter conditions it has been shown that standard 2″ iron or steel ppie may not last much over two years. We have found that by passing heated water through a bed of iron trimmings about 18″ deep, in which weighed samples of steel plate were placed at the top and bottom, that the top samples pitted badly and lost about five times more in weigh than those pieces at the bottom.

This has been a mere outline of the principles of corrosion, as we understand them at present, in an attempt to show their practical application. The subject is being energetically investigated, and further development may be expected in the near future.

A PRACTICAL SYSTEM OF REINFORCING CONCRETE

*H. F. PORTER, C.E.

When I was asked to address this meeting I did not expect to have the honor of taking sides, as it were, in a debate on the subject of reinforcing systems. As it happens the preceding speaker has exploited to you the merits of one distinct type, which involves the use of rigidly attached diagonal stirrups to the main reinforcing member. The system which I shall endeavor to explain is based entirely upon the use of plain bars, which can always be obtained readily and at the lowest price per pound. Working along this line, we have endeavored to develop a logical, practical, and economical system of reinforcement that would meet at the same time, in so far as possible, all theoretical and practical demands of an ideal system. How far we have succeeded, I shall leave you to judge. In any event, in the large number of installations in which this system has been used, we have enjoyed unusual success, not alone in keeping down the costs, but in making possible rapid construction, accuracy of work and the realization of a large factor of safety. The exponents of a leading American system of patent bar reinforcement, I refer to the Kahn bar—claim to have developed factors of safety of ten and eleven, whereas the building laws have required only a foctor of safety of four. With this system of plain bar reinforcement, which I shall try to explain to you, factors of safety as large as thirteen have been attained, and in every case where failure has resulted, it has been by pulling in two of the horizontal reinforcement and not by failure of the concrete in diagonal tension or compression. Evidently, then, as this is the ideal method of failure, we have in this system provided properly for all of the stresses.

The preceding speaker has explained to you the theory upon which the system of reinforcement using rigidly attached diagonal members is based; and for freely supported rectangular reinforced concrete beams there is no gainsaying that this is a proper and also an economical method. However, in practice, beams of this character are rarely encountered. Instead the ma-

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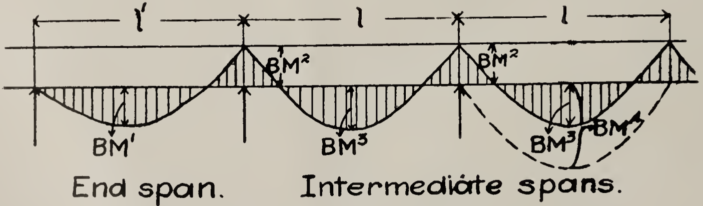
*Engineer for Wm. Steel & Sons Co., of Philadelphia.

jority of beams will be continuous over several supports and being monolithic with the floor slab, will act in every case as T-beams. There is one exception—the end span—in which at the best only partial fixity of construction can be secured; but, by properly adjusting the length of spans, this weakness of the end spans may be compensated for, allowing the use of the same reinforcement throughout. If the end span cannot be made shorter than the intermediate spans, then it will be necessary to provide for the loss of strength by increasing the amount of steel. For practical purposes it is advisable to preserve uniformity in the amount and kind of reinforcement, so that the former method is preferable.

The subject of continuity is one that engrosses the entire engineering world to-day. There is no question whatsoever that concrete, in view of its monolithic character, must develop continuity of action, and it seems, therefore, logical to work on this basis in developing a satisfactory method of reinforcement. True, the building laws of practically every city on the American continent prescribe that reinforced concrete members shall be calculated as freely supported—that is, steel shall be provided on the tension side to satisfy the equation, ⅛ WL, which those of you who are familiar with the mechanics of engineering will recognize as the value of the bending moment in a freely supported beam for uniformly distributed loading. The plain fact that continuity of stress is bound to exist is very largely ignored. The new building code of the City of Philadelphia, issued in November, 1907, is the first one to require provision for continuity stresses. Yet, it has not, in my opinion, gone far enough, in that no allowance is made for continuity, beams being still required to be figured as freely supported. To show you the great difference in the amount of steel necessary, I would ask your attention to the following diagram, which represents approximately the character of the stresses realized in beams continuous over several supports. You will note that to all practical purposes, the bending moment in mid-span may be represented by the equation 1/24 WL, and the bending moment over the support,



Adjust l' to l to make $BM' = BM^3$

$BM^2 = \frac{1}{12} wl^2$ (near enough)

$BM^3 = \frac{1}{24} wl^2$ (" ")

$BM^4 = \frac{1}{8} wl^2$ for freely supported

Diag I

known commonly as the negative, bending moment, by the equation 1/12 WL. Obviously, then, to calculate beams as freely supported that in construction are bound to be continuous, is to provide three times as much steel in mid-span as the actual stresses require, and, if along with this error, the negative bending stresses are partially, if not wholly ignored, there is uncared for a stress represented by 1/12 WL over the support, and the plain result is, if the member is ever loaded to its calculated ultimate carrying capacity, parting of the beam over the support is inevitable. Moreover, in practically every failure of a reinforced concrete construction this neglect to provide for continuity stresses has been largely responsible for collapse. This fact has not been sufficiently realized, for, in nearly every case, the cause of the failure has been assigned to premature removal of the centres. On the contrary, premature removal of the forms has not been the cause of the difficulty, but, has only brought to light, defects in design and installation. Like charity, "it covers a multitude of sins." In nearly every case, failure would have been either entirely prevented, or, not been nearly so extended, if proper provision had been made for negative bending stresses.

Bearing the foregoing facts in mind, let us proceed to examine practically a typical reinforced concrete layout, and to adapt a system of reinforcement to best meet the conditions, which may be summarized as follows:

(1) That it will provide for all stresses horizontal and inclined.

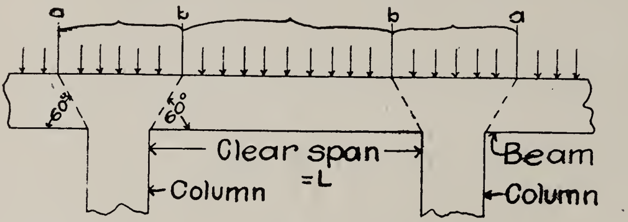
(2) That is will permit of the use of plain bars without the necessity of shop fabrication.

(3) That it will permit of easy and rapid, and, therefore, economical and safe installation.

Let us examine the first condition. In all failures of concrete beams wherein only horizontal reinforcement has been provided, the first sign of yielding has been a diagonal crack extending upward and outward at an angle of between 45° and 60° horizontal from the edge of the support. This is commonly known as failure by sheer; correctly speaking, it is failure in diagonal tension, for pulling apart of the concrete along the diagonal line above mentioned which defines the region where a reversal of tensile stresses from the bottom of the beam to the top ensues. Evidently this failure can be prevented by providing sufficient diagonal steel normal to the plain of separation to care for the stresses, tending to disrupt the beam at this point. How shall we ascertain the amount of these stresses and provide for them to the best advantage practically—this is the issue.

Let us examine for an instant a plain concrete or masonry footing with superimposed column. Now it is a well-known fact that if the footing slopes off from the edge of the column at an angle of approximately 60 degrees with a horizontal, the internal or cohesive strength of the material is sufficient to develop the full bearing value of the footing without danger of cracking. A concrete footing of this design would obviously need no reinforcing. The analogy is close between this case and an earthen embankment. If the soil slopes at the so-called angle of repose of the material, no restraining wall or other means is required to hold the earth in position; so, in a concrete footing, if the slope does not exceed the angle of friction of the material, no reinforcement is required

Now let us consider the footing and its column inverted. Have we not then the same condition as is realized in every reinforced concrete construction? It is perfectly apparent that the portion of the beam over the support encompassed by the 60 degree lines is capable of transmitting its load into the support without the assistance of any metal. This reduces the loading on the beam which produces bending in mid-span to the portion between the upper ends of the same 60° lines. We need therefore provide reinforcement in the lower side of the beam to care for the bending moment produced by this reduced loading over the clear span between supports. The tendency obviously is for this mid-portion of the beam to slide out of position, even though the horizontal tensile stresses may be adequately provided for. This explains the failure due to diagonal tension of beams in which horizontal reinforcement alone is provided. To counteract this tendency, the simplest plan seems to be to bend up some of the horizontal steel, where it is no longer required to take horizontal tension, and carry it through this plane of diagonal tension normal to it in amount sufficient to take care of the component stress along this plane. This is made clear on the diagram. This diagonal steel must, of course, be anchored securely at either end in order to be effective; at its lower end it is a part of the horizontal steel which very effectively anchors it; at the upper end equally as effective anchorage may be secured by carrying the same bars across the support and down into the adjacent span. As an additional precaution this end may be hooked, a device which somewhat assists the bond. Or, as is our practice, the bar may be carried down into the adjacent span and used there, one span being thus anchored against the other and an absolute tie provided across the support.

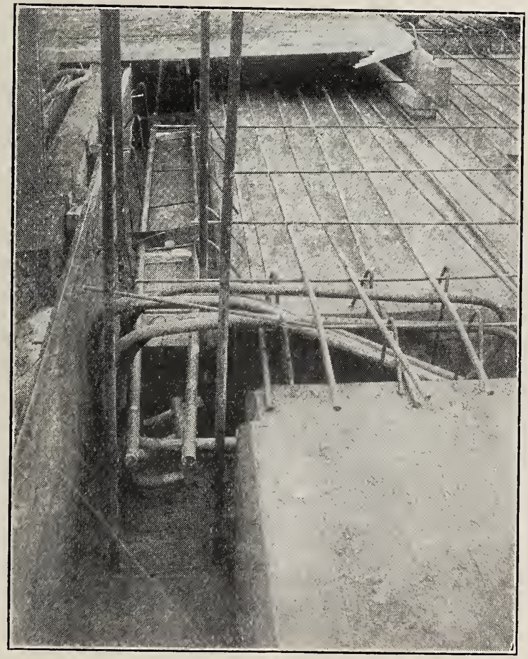


Load "a" to "b" produces no bending
Load "b" to "b" produces bending over span =L onl

Diag II

In a series of spans by using this system of double length bars, in alternation, absolute continuity of the reinforcing is practically insured throughout the construction. This feature not only is an effectual guarantee of safety, but it increases the carrying capacity considerably. A further advantage afforded is the early removal of forms possible which is an economical factor not to be made light of.

The similarity between the foregoing method of placing steel in beams and the catenary curve, which is the form assumed by a loaded cord freely suspended, is apparent; and in fact, if the steel were placed in exactly this position and provision were made for the full development of the steel at every point, the analogy would be perfect. Then the steel would be at all points in correct position to assume all tensile stresses leaving the concrete to act only in compression and to restrict the steel to definite lines of action.



Typical Reinforcement for Columns and Beams
F. H. Fleer Building, Toronto

There is, furthermore, an analogy between this method of placing steel and a parabolic bow string truss. Those of you who are familiar with the mechanics of bridge construction will recall the remarkable property possessed by the parabolic bow-string truss in that there is uniform tension throughout the tension chord and uniform compression throughout the compressive chord of the truss.. This fact is of marked economic advantage, inasmuch as it permits of the use of the same section of metal throughout. The same advantage obtains by simulating the parabolic truss in designing reinforcement for reinforced concrete.

It will be apparent that if the steel were placed to satisfactorily fulfil the catenary principle, no further reinforcement in the beam would be needed, which would theoretically be correct. However, in practice we find it advisable to use vertical stirrups throughout the member, although theoretically their presence might be considered superfluous. There are two reasons which justify the use of stirrups in this connection. Firstly, that, inasmuch as T-beams are almost invariably realized in actual construction, economy justifies the use of narrow deep beams which calls for the use of a certain amount of vertical steel to tie the compression flange to the rib. Especially do stirrups become an absolute necessity when in the course of installation it becomes impossible or impracticable to pour the soffit of the beam and the superimposed slab which forms its compression flange at the same time. Stirrups of the proper type and liberally spaced throughout the length of the beam become in this instance an effectual agency in unifying the parts of the beam. Secondly, stirrups are a practical advantage in that they may be utilized to carry, as in a saddle, the main reinforcing bars. It might be added that in general it is a good principle in dealing with concrete to have some steel running in all directions horizontally, diagonally and vertically; and, moreover, vertical stirrups are indisputably an addition to the strength of the beam because of their action as vertical tension members of a Howe truss system. A system of reinforcement along these lines evidently meets the first criterion of an ideal system, namely, that it provides for all stresses.

Placing Steel for Floor Slabs and Beams

The second condition to be satisfied is that plain bars only need be used as they come from the rolling mill without the intermediate step considered indispensable by many engineers of shop fabrication. In the early days of reinforced concrete construction, and, very largely yet to-day, little or no attempt is made to secure accurate placement of the steel, and as a natural result wide prejudice has been engendered in the minds of engineers against so-called loose bar installations. This problem, we believe, has been satifactorily solved in the system now being explained. With the aid of a few simple accessory devices which are made clear on the accompanying illustration we believe we have made it entirely possible to use plain bars without shop fabrication, without undue expenditure of time and money in the field, and with absolute assurance that all steel will remain in position intended throughout the operation of installation. Moreover, this is accomplished without excessive expense for inspection, and the possibility of mistakes is also largely reduced.

The third criterion follows naturally—certainly a system that satisfies all theoretical conditions, ensures accurate placement of the steel, has the possibility of error reduced to the minimum, and that requires less inspection than any other system that has come to the writer's attention, will be easy and rapid, and, therefore, economical and safe in installation. The principle followed out in constructing a reinforced concrete floor under this method is, briefly, as follows: Place each item of the steel in logical order, and when once placed and inspected know that it will stay there, then, when sufficient steel has been placed for a day's work in advance, the operation of pouring concrete may be begun and continued without interruption.

This method not only ensures correct work, monolithic construction throughout and a better quality of workmanship, but, by eliminating the element confusion in a large measure, greatly increases the effectivenes of the organization, thereby making possible more rapid construction and needless to say more economical. In a typical instance, for example, in an eight storey factory building in Philadelphia, of approximately 10,000 square feet to a floor, stories were added at the rate of one in every seven to ten days throughout the job. Interruptions of weather alone delaying. The cost of the steel in position exceeded very little, $40 a ton reckoned from a base of $34 a ton; and the total cost of mixing, hoisting, placing and tamping the concrete averaged, under favorable conditions, close to forty cents a cubic yard and never exceeded seventy-five. A twenty-two foot span girder in this building, when tested, to three times its calculated carrying capacity deflected less than three-sixteenths of an inch, which is about half the allowable deflection prescribed by good practice, namely, 1/800 the clear span. The loading was so arranged as to obviate any arching that would defeat the spirit of the test. The slabs in this building, when loaded three times their capacity, showed absolutely no indications of deflection. In another building constructed smilarly, a floor designed according to the city building law for 120 pounds live load, was loaded up when only thirty days' old to over 600 pounds a square foot and gave no sign of yielding whatsoever.

In conclusion, I would say that what has been presented to you in this paper represents the honest attempts of engineers having neither hobbies nor prejudices, but seeking only to secure with the simplest means at hand, the most practical system of reinforcement. It has been adopted widely in Philadelphia, and is being used in the reconstruction of the Bridgeman Brothers' factory, which collapsed last spring. While not by any means ideal, it seems to be in the way of progress, and the results obtained are certainly a justification.

Gentlemen, I thank you for this opportunity and for your warm interest, kind attention and courtesy.

SEWAGE DISPOSAL FOR INLAND TOWNS

MARCEL PEQUEGNAT, '08

Mr. President and Members of the Engineering Society:

The question of sewage disposal is one which, at the present time is confronting many of our engineers, especially municipal engineers, and it seems quite in place to open a discussion on the subject here, in the Engineering Society. I certainly feel quite incapable, with the little experience I have had, to do justice to the subject, but I hope that this paper will prove at least of some small interest to you all.

Towns and cities bordering on large bodies of water, lakes or rivers, do not experience the real difficulty of sewage disposal. It is the inland town that has to face the trouble and a very serious one it is. Very few towns are so unfortunate as to be entirely without flowing water but in most cases it amounts to a little creek, perhaps ten to fifteen feet wide, hardly deep enough for the little boys to swim in, and this is the stream that must unburden the town of its sewage, no matter how large that town may be.

There are many reasons which forbid allowing the pure sewage to enter such a stream, and even larger one; I will enumerate five important ones.

1. The contamination of water and ice supplies.
2. The destruction of fish.
3. The danger to health.
4. Legal rights of land-owners along the course of the stream.
5. Unsightly appearance since stream becomes merely an open sewer.

It is therefore very important that an inland town finds some method of purifying the sewage before allowing it to enter the stream and thus free themselves from any trouble with the people in the neighborhood. Before the Town of Berlin put in its present system, which I will describe briefly a little later, they had to face this difficulty; dozens of farmers along the course of the stream sued the town for damages, and as the town could not put in any defence, it had to pay claims to the amount of $20,000.

There are several methods used for the purification of sewage, but the septic tank with sand or gravel filtration seems to be taking the upper hand, and I shall describe such a system.

The simplest way will be to take a definite system, and trace the course of the sewage through it. The Town of Waterloo affords a good example.

Up to the present the sewage has been deposited on a farm about a mile from the town. The ground had been graded to form filter beds, but they were not of the right material, they got choked quickly and the sewage was practically dumped into the stream without any filtration. The town saw trouble ahead and accordingly proceeded to remedy matters. A sewage commission was formed and they lost no time in getting to work. The intention at first was to use the old farm, build it up with gravel beds and put in tanks, but they were held up for gravel, besides the beds were not high enough to allow for proper filtration. They accordingly looked for a better site, and found one with gravel about a mile farther down the creek. They purchased the farm, which had hills on either side the creek, and then came to an agreement with the farmers along the line for a 15′ right of way for the trunk sewer. The town has the right to build the sewer, and enter their places at any time for repairs, etc. This part completed, the plans for the farm were prepared, the size of the farm was to be sufficient to look after the sewage for many years to come.

The Town of Waterloo has a population of about 4,000 and the sewage to be disposed of amounts to 250,000 gallons in twenty-four hours. It required a 15″ pipe, having a fall of 2½″ per 100′, to carry this sewage to its destination, and to provide for an increase in the future. The stream falls slightly faster than this and in this way about 3 or 4 feet of extra head is obtained at the works.

The fall of the sewer being so slight it is very important to lay every pipe exactly to grade and to see that all joints are made as smooth as possible. To get the grade the engineer plants solid hubs every 200′ and over these erects bridges at some definite height, say 8′, above the grade of the pipe, then by using a boning rod, as they call it, which is exactly 8′ long, the contractor can get the exact level of each pipe between the stations by sighting over these bridges. Manholes are built at each bend of the sewer for inspection and ventilating purposes. The contractor is supposed to make every joint water-tight, the sewer not being built to drain the land, but it is almost impossible to watch them lay every pipe, especially if the inspector must supervise gangs at some distance apart. A good way of getting over this difficulty is to let the contractor understand that he must find where the leaks are, if water enters the pipe and shows itself at the manholes, and it is therefore to his interest to see that the joints are right. In a swampy place where a foundation has to be built to support the pipe the contractor is allowed extra, at a price, generally per cubic yard, given in the agreement.

The disposal works are situated on the opposite side of the creek from the trunk sewer, and the sewage has to be taken across. In order to do this the sewage passes through an inverted syphon. The sewage is freed from sticks and other such matter by passing through a cast iron screen; it then drops into a manhole 9½′ deep and crosses below the stream through a 15″ cast iron pipe, and again rises in a manhole at the mouth of the septic tanks. There is a slight danger of this inverted syphon becoming blocked up, but this is overcome by having an opening directly into the sludge drain, which will be described later. The sewage has about six feet of head to shoot it through the syphon.

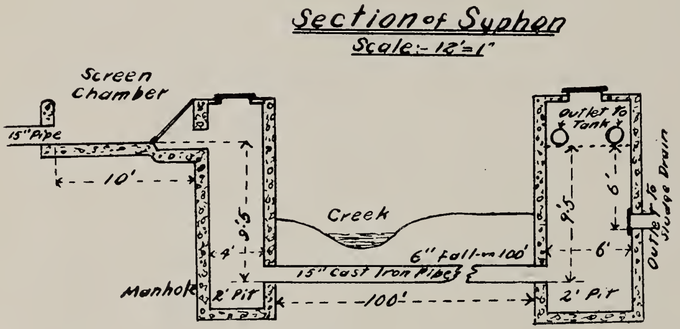


Fig. 1

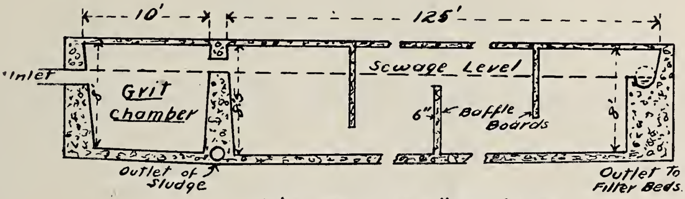
The sewage then flows into the septic tanks. There are two separate tanks side by side, so that while one is being cleaned out the other can be kept in use. The sewage first passes into a "grit chamber" where the sand, etc., is deposited, being heavier than the ordinary sewage. This chamber is 26′ long, 10′ wide and 6½′ deep. The sewage then passes into the septic tank proper. This tank is 125′×26′, about 6′ deep, having a capacity of 120,000 gallons. Here the sludge settles to the bottom, and the remaining fluid drops over a level overflow into the distributing chamber, which distributes it to the different filter beds. Each tank is provided with baffle boards to insure the settling of all the sludge. The tanks are built large enough to hold all the sludge for the entire year, and thus have only to be emptied once in that period. The grit chamber, being small, has to be emptied after every heavy rainfall, for at those times much mud, sand and small stones are washed down through the sewers. The floors of the tanks are slightly inclined, so that the sludge can flow into the sludge drain, pass under all the filter beds and be deposited on a special bed, having an elevation below that of the bottom of the tank.

This sludge is allowed to dry out, and then is raked up in heaps and burnt. In some parts of the country the farmers are eager to obtain the sludge for fertilizing purposes, but in that district they seem to be afraid of it and it must therefore be disposed of as described.

Sewage, as you all know, is almost entirely organic matter, having some useful bacteria and some of no use, and even dangerous to life. The useful bacteria act as scavengers for the others.

Section of Septic Tank

Scale:- 12'=1"



Note:- Roof is a 4" Reinforced Concrete Slab.
Floor- 8"
Walls - 18" top, 30" bottom

Fig. 2

The septic tank is an arrangement for nursing bacteria which act in this way on organic matter, and to promote fermentation. It gives them a chance to act rapidly and reproduce their kind, in the tanks by running in nutritious sewage. The greater part is converted into CO_2 marsh gas and H, which escapes into the air. The rest settles down at the bottom, as harmless sewage, and is disposed of as already described. The septic tank is ahead of the precipitating tank, *i.e.* treating the sewage with lime or some other substance, for in that process nearly all settles and more room is required.

The bacteria of disease may or may not be destroyed by bacteria in septic tanks, but they are solid and settle down in the tank, so the septic tank is at least a great defence.

From the tanks the sewage is run by means of distributors and carriers over the filter beds. They cover an area of about 3½ acres, the whole space being divided up into six beds. These beds are constructed as follows: The sub-grade is first formed, having a slight slope toward the effluent drain. The drain is laid through the centre of the bed of 8″ field tile, and from this 4″ tile are run to the edges every 20 feet. This formed a good subsoil drain to carry off the effluent after filtration. Above this is deposited a layer of gravel and sand, having an average depth of four feet. the surface being made as level as possible. A cement carrier is run across the centre of the bed, thus distributing the sewage evenly over the entire surface.

If a filter bed of this kind is treated properly it will last for a very long time before it is choked up. After being in use for some time, it needs a rest to rid itself of the impurities it has taken in, and after a rest it is just as fit as before to carry on its work of filtration. The filtrate is then carried through the effluent drains to the creek, but now in such a condition of purity as to cause no trouble to man or beast.

The system described is entirely carried on by gravitation, the expense being considerably less than where pumping has to be done, especially since all the material was so close at hand. The cost of the work might be of interest to some; the contract price for the making of the 3½ acres of filter beds was about $11,000, and for the septic tanks and connections $6,500, the town supplying all the iron and steel necessary in the work. The work is not yet completed.

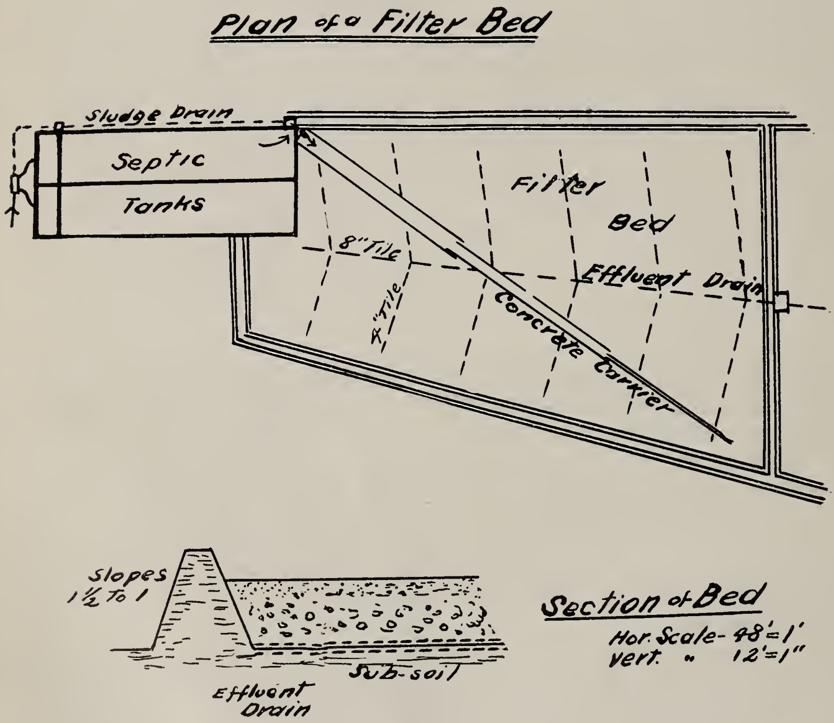


Fig. 3

My travels have not been extended, and you will have to excuse me for keeping within the bounds of my own native county, but I believe that a little information of the system installed in Berlin, Ont., and which has proved a great success, will be of interest.

Berlin also had an old sewer farm of the style of Waterloo's which had long since seen its best days, and before the new system was constructed the sewage practically emptied into the creek, and hence the trouble with the farmers in the neighborhood.

The population of the town is about 13,000, and the amount of sewage is from 600,000 to 700,000 gallons in 24 hours, the trunk sewer being only 18″. The tanks are composed of two septic and two storage tanks, total size being 300′×75′ and 6½′ deep, a capacity of 900,000 gallons. The pumps cannot be continually in motion, hence the need of storage tanks, to hold the fluid sewage after it passes through the septic tanks. The sewage is pumped by means of two centrifugal pumps, each of 1,000 gals. per minute capacity, direct connected with a 50 h.p. induction motor, and there is a special pump for pumping up the sludge of capacity 500 gals. per min. The force main is a 14″ cast iron pipe, a length of 2,000′, and rises in that distance to a height of 60′. In this way the town makes use of natural sand hills, which have been levelled off for the filtration of its sewage. There are 10 filter beds, having a total area of 14 acres. The sewage has thus to soak through considerable sand before it reaches the creek 60′ below, and hence reaches a state of great purity. Chemically the effluent from the Berlin farm is purer than the water the people drink, and the water there is not much worse than in other places. A gang of men were laying a tile drain to drain off some of this effluent, and they used it freely as drinking water, not being satisfied with the water brought them from a neighbouring well.

As I have said before, tanneries, etc., cause the greatest nuisance, and to overcome this the town has passed a by-law forcing all such institutions to construct settling tanks of their own, and to pass the sewage through them before allowing it to pass into the town mains.

As I have said before, Berlin's system has proved to be a great success, but there is at the present time a small source of trouble. Part of the filtrate from the filtration beds is finding its way over the land of the adjoining farms. They have attempted to stop it, by means of sub-soil drains, run around the beds, but they do not seem to catch the water. The farmers are complaining of wet land, so it will probably be necesasry for the town to purchase the land in question, which is not a very serious matter.

Many are of the opinion that all the water from the street, etc., passes into the sewer, and has to be treated along with the rest of the sewage. This is, however, not the case, and were it so, the disposal plant would need to be considerably larger. The storm water, and even the cellar-draining system, has pipe lines of its own, and is turned into the creek at its nearest point.

I consider it agreat honor to have had the privilege to give a paper before the Engineering Society, and I must thank your worthy President for giving me this opportunity, and trust that it has not taxed your patience too far.

STADIA TOPOGRAPHY

W. TREADGOLD '05

The adaptation of plans to the purpose in view constitutes the aim of the civil engineer. However general in scope a method may be, it is modified in characteristic details by ever varying requirements of natural conditions of the project and of the necessary cost. The appreciation of the conditions involved characterizes the successful project, whether in the survey, design or construction of engineering work.

Realizing this, I will endeavor to consider separately and independently the different methods of executing a topographical survey and point out how far they are effected by conditions of amount of detail required, cost and general adaptability of the country to be surveyed.

Originally, the prevailing opinion regarding the use of the stadia was that, at best, it would answer as a rough expedient, comparable rather to pacing than to chaining as regards accuracy. However, among those familiar with its use its great value has been recognized and its adoption advocated where precision of not more than 1 in 1200 would be allowable. That it is more accurate than chaining, even after the correction of several large errors caused by a miscount of the number of chains, is evidenced by its use not only in the smaller surveys, such as location of possible reservoirs and conduit lines for waterworks and sewage systems but also on large extended surveys such as made by the governments of the United States and Canada.

The principle of the method depends upon that of similar triangles or upon the fact that the lengths of parallel lines which subtend a constant angle are proportional to their distances from the vertex of the angle, or, to be more definite, if two parallel wires

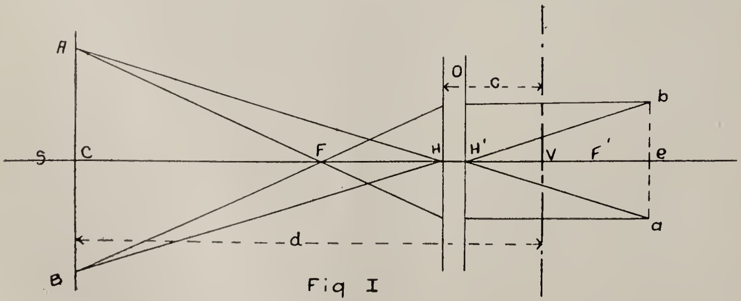


Fig I

be placed in the focus of a telescope and it be directed to a graduated rod held so that its length is perpendicular to the line of sight of the telescope, the length of the rod between the points covered by the wires is proportional to the distance of the rod—from what point must be determined on optical principles.

In the figure, $A\ B$ represents the graduated rod, O the object glass of the telescope, of which H and H^1 are the principal points, F and F^1 the focal points; a and b are the positions of the stadia wires. The diagram shows that A and B are the points of the rod intercepted by the cross wires.

Let $S = AB =$ length of rod intercepted by cross wires.
$e = ba =$ distance between cross wires.
$f =$ focal length of the objective.
$d = ev =$ distance from the position of the rod to the centre of the instrument.
$c = HV =$ distance from the object glass to centre of instrument, V being the point in which the vertical axis of the instrument intersects the axis of collination if produced upwards.

By similar triangles $F\ A\ B$ and $F\ D\ E$

$$\frac{C\,H}{F\,H} = \frac{A\,B}{D\,E} \text{ or } \frac{d\text{-}f\text{-}c}{F} = \frac{S}{e}$$

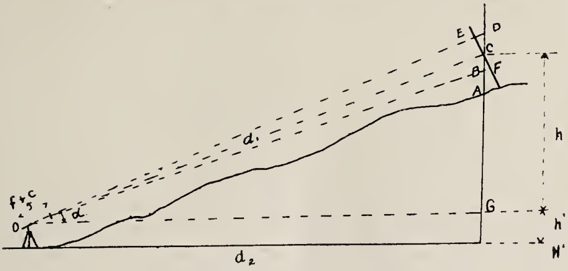
or

$$d\text{-}f\text{-}c = \frac{f}{e}\,S = KS$$

when K is the constant ratio of the focal length of the objective to the distance between the stadia wires.

Thus we see that the length of rod intercepted between the stadia wires is proportional to the distance of the rod from the outer principal focus of the objective of the telescope.

This applies to a level sight or to an inclined sight in which the rod is held so as to be perpendicular to the line of sight. It is usual, however, to hold the rod always vertical, irrespective of the inclination of the telescope.



Suppose

$o\ c = d_1 =$ inclined distance from rod to instrument.
$o\ G = d_2 =$ horizontal distance required.
$C\ G = h =$ difference of elevation of O_1 and C.
S_1=part of rod intercepted when held perpendicular to the line of sight.
S=Part of rod intercepted when held vertically.
$\alpha =$ angle of inclination of the telescope.

Since $O\ E$ and $O\ F$ are very nearly perpendicular to the line $E\ F$ then $S_1 = S \cos\alpha$

But we have already proved

$$d_1 = (f + c) + K S_1 = (f + c) + K S \cos\alpha$$

in the triangle $o\ c\ G$ we get

$$d_2 = d_1 \cos\alpha$$

and $$h = d_1 \sin\alpha$$

Hence $$d_2 = (f + c + K S \cos\alpha\ ) \cos\ \alpha$$
$$= (f + c) \cos\alpha + K S \cos^2\alpha$$

also $$h = (f + c) \cos\alpha + K S\ \sin\alpha \cos\alpha$$

If then we are given the elevation of the point of set up, H^1, measure the height of instrument h^1, m the reading of the middle cross wire on the rod and H the elevation of the point sighted we get $H = H^1 + h^1 + h - m.$

In order to get results we must obtain the values of the constants f and c.

f is the focal distance of the object glass and is obtained by measuring the distance from the object glass, when the telescope is focussed on a far distant point, to the intersection of the cross wires.

c is the distance measured from the intersection of the horizontal axis and axis of collination to the object glass.

$K = \frac{f}{e}$ and the spacing of the wires is made so that the value of K will equal 100.

There are many designs for the stadia rod and in each it is essential that they should combine simplicity, clearness, distinctive divisions and subdivisions and efficiency in indicating the shorter distances very accurately and in giving great distances readily. That it should be divided into true unit lengths, such as feet, is desirable for many reasons. It makes impossible any error due to an accidental interchange of stadia rods among transits; any stadia rods not especially constructed for the particular transit may be used in case of emergency or desirability, viz., level rods may be used for stadia readings for stadia railroad preliminary surveys. There are also other considerations that make this almost a necessity; the one that the distance above the stake at which the middle wire stands when the vertical angle is measured may be read in the linear distance; the second, that error in the stadia interval, occurring either from a change in the cross wires or from a subsequent determination indicating that previous determinations have not developed the true and exact factor, may be corrected without the complete change of the stadia rod divisions, which would at best consume several days of delay and careful work.

However, very often cross wires are placed in the diaphragm by the topographer himself and to suit the spacing of the wires he graduates the rod in the following manner. He measures carefully some convenient distance from the instrument, say 600 feet, and marks on a blank rod the length intercepted between the stadia wires; a sixth part of that length is then the unit according to which the rod is to be graduated and the number of those units contained between the stadia wires when the rod is held at any distance from the instrument will indicate that distance in hundreds of feet.

We have seen from our formulae

$$d = (f + c) \cos \alpha + K S \cos^2 \alpha$$

and $$h = (f + c) \sin \alpha + K S \sin \alpha \cos \alpha$$

but it is a very common practice in some quarters to assume that the distance is directly proportional to the space intercepted by the cross wires, thus neglecting the quantity $(f + c)$ whose value ranges from 1.00 to 1.25 feet generally.

In so doing we obtain a new value for the constant K by measuring out a distance which will be equal to about the mean of the distances expected to be measured.

It will be found that this gives errors in the true distances, which in any case do not exceed $(f+c)$, some of which will be positive for distances less than the measured distance and negative for distances greater and the tendency will be for the errors to cancel one another.

Some instruments are provided with an additional lens called an anallatic lens, which moves the vertex of the reading angle from the outer principal focus up to the centre of the instrument thus enabling you to read directly the distance the rod is held away, thus getting rid of the constant quantity $(f+c)$—with a lens of this kind in the telescope the approximate values of distance are correct. This instrument, which, by the way, goes under the name of Tacheometer, has one disadvantage and that is the loss of light necessitated by addition of the extra lens.

The basis of the detailed topographic work is usually a traverse line, the stations being marked by hubs in the ordinary way and the work generally involves the instrumental location and determination of the elevation of all surface irregularities and the positions of roads, trails, towns, ranches, wood, cultivated land and water. The datum from which all elevations are reckoned may be assumed with reference to the original station. The horizontal angles are best measured by the traverse method, that is, azimuths are carried continuously and measure the deviation from the meridian. For measuring vertical angles the best graduation is one that gives the zenith distance of the point sighted thus avoiding the necessity for distinguishing between the positive and negative altitudes. The degrees of the two halves of the circle number from a common zero in opposite direction to 180° and it is so placed on the axis that when the sight time is vertical one vernier reads zero and the other 180°; thus on sighting any point the one vernier will give its zenith distance and the other its nadir distance in either position of the instrument. However, as this graduation is seldom met with it is assumed in the formulae used, that α is the altitude of the point sighted. On a small survey the party would consist of a transitman and two rodmen and one axeman, but on an extended survey like that, say, of the boundary between Mexico and the United States or Canada and the United States, there are several parties to do the work. On boundary work topography is taken for two miles on each side of the boundary line. One party would work along the boundary line itself taking distances and elevations, this line being considered as the true basis for all after work, a second and third party would then do detail work on each side of the boundary. These parties would start with the bearing of the line at a starting point of the base line and run out a traverse at right angles until they had gone as far as necessary and then return by another route thus checking back on the original base line by making a complete circuit. At each setting of the instrument measurements would be taken on all the distinct points of the ground and so the greater number of side shots taken the greater information you would have and the map would then furnish more completely all the detail. The occasional remoteness of the work from available camps, the very rough and difficult nature of the regions encountered, sometimes makes it advisable to withdraw the party engaged in running out the base line from their usual work to reinforce the others, all parties then working advantageously together on pure topography.

Occasionally ground is covered by means of a method of intersections. In this region there are say several commanding peaks below which lay the ground in all its irregularity, the general procedure here consists in the establishment of station signals on those commanding peaks and from numerous stations on the boundary the base line transitman will take azimuths and vertical angles to these signals from which the location and elevation of each station is computed; then these same stations are occupied two at a time in such order as to give the best intersections on points to be located. An engineer with a flagman, using horses where the country will permit, will traverse an advantageous area; the flagman signals at each necessary point of the area and the engineer makes a contour sketch of the ground showing the position of the points from which the signals are made, at the same time the two transitmen at their stations watch the flagman and on a signal from him, each takes the azimuth and vertical angle to his signal held vertically on the ground, the engineer and transitmen all note the time of each sight to have a check distinguishing corresponding observations. Topography taken in this way is not capable of the accuracy of the usual method but at times is advantageous and is used to facilitate and hasten the work.

This then represents in a small way the manner in which a stadia survey is often carried out. Experience tells us that for general economy, adaptability, and efficiency it is unequaled and as a consequence on topographic and railroad surveys, canals and other public works this method is rapidly superseding all others.

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Editorial

Do the University Alumni Lack Esprit de Corps?

The critics of the University in past years claimed that among the many things it lacked, was a proper, vital, esprit de corps both among the graduate and undergraduate bodies. They claimed that with the great mass of the Alumni there was no bond of sympathy between either themselves or their Alma Mater; that, to the average graduate, to be a Toronto man had no special significance; his college days were merely a memory, no different from other associations; that the average graduate felt in no way bound to keep in touch with his Alma Mater; that, at most, his interests went out to the members of his own faculty and his own year; those of other faculties and other years were of no more interest to him or had they more claim on him than the natives of the Fiji Islands. In other words, Toronto University had not put its stamp on them.

Does the School Lack Esprit de Corps?

Just how true the above is concerning the University as a whole we are in no position to judge. One thing is certain, however, that it is not true of the "School." Once a School man always a School man, seems to have been the motto. The reason for this is obvious. The men in the Faculty of Applied Science have a better opportunity of becoming acquainted with each other, in the field and drafting rooms, than those in other Faculties. Again, in early days when attendance was small we had to make a fight for recognition. "Toike, oike, Toike, oike," often assembled the boys either to battles of offence or defence when shoulder to shoulder they fought for the honor and glory of the School. Just how much effect these scraps had on the cementing of friendship and the arousing of that feeling of mutual help which all School graduates carry with them into the world is hard to say, but that it has had some no one will deny. Once a School man quoted, as he said from Shakespeare: "Verily, when one or two School men have been hired in one place, you shall soon see another one."

An Employment Bureau

What our graduates have done for each other in the past in the matter of furthering each other's interests professionally, and what has been done by the staff with a limited organization, the Faculty and Engineering Society propose to take up systematically in the future. The publication of "Applied Science" was one of the first steps in the scheme. In the first place we wished to get the addresses of all the graduates, to get in touch with them, and, we hope, to keep in touch with them in the future. The response in the shape of subscriptions has been very gratifying.

In the course of the next few weeks every graduate will receive a blank form requesting information concerning himself and his professional career. We purpose starting a card index of all our graduates and undergraduates together with all available information concerning them. This information will be regarded as strictly confidential when necessary or desirable.

Repeatedly we have firms and individuals writing in for competent men on engineering works and we have been without the necessary information to recommend suitable graduates to them. Frequently we have been able to secure positions for our men who were thoughtful enough to keep us informed of their experience and whereabouts.

It is expected that when we have completed this proposed index and have acquainted the commercial world of the fact, that an important work will be done in this department.

The professional record of all graduates is wanted even if they have no intention of making use of the employment department. We want to know just exactly what you have accomplished; to show that our men measure up with those of other universities. We wish to show that we can justify our existence —that the money spent by the country in educating engineers has been well invested in furthering the development of the country.

Request for Information.—On another page there is a list of men whose addresses we have been unable to verify in the last year or two. Examine the list carefully and if you can supply the information as to their present whereabouts—if living—let us know immediately.

The Future of Niagara Falls

In the light of the discussion at the present time, of the Hydro-Electric Power Commission Policy and municipal ownership of transmission lines for electric power, we ought not to lose sight of the issue raised about a year ago on the question of taking water from the Niagara River for power purposes.

It will be remembered that in 1905 there was throughout the United States a widespread public sentiment against the granting of any further privileges of the withdrawal of water for the developing of power.

This sentiment was no doubt greatly fostered by the appearance at that time of certain magazine articles, some of them grossly untrue, calling upon the public to petition the government against such grants and suggesting at the same time that international action be taken to prevent any further grants in the future, in order to prevent complete devastation of the Falls. To illustrate the unreliability of the magazine articles above mentioned it will be sufficient to quote from one of these. The statement was made that further withdrawals of water from Niagara River would mean a lowering of the level of the Welland Canal and thereby be a menace to navigation. When it is understood that the point on the Niagara River at which water for power development is taken is a short distance above the Falls and many miles below the intake of the Welland Canal on Lake Erie, the fallacy of the above statement is apparent.

However, public sentiment in the United States was aroused by such articles and strong appeals were made to the Governments of both the United States and Canada to intervene on the ground that the river was an international stream. The United States Congress and Senate in 1906 passed an Act called the "Burton Bill" which provided for the control and regulation of the waters of Niagara River and the preservation of the Falls, this Act to remain in force for three years from date of passage.

Should Canada Sacrifice Her Rights?

At the present time considerable pressure is being brought to bear on the Canadian Government to co-operate in the restriction of withdrawal of water. At first sight the scheme to the average Canadian looks quite just. The United States Government says: "We have restricted the use of this water for power purposes in order to preserve the Falls for future generations. It is a heritage which has been handed to us and we ought to pass it on unimpaired." But when you find the American Government more than willing to meet the Canadian Government half way, it is wise to go slowly. The truth of the matter is this. The American Falls is about six feet higher in elevation than the Horseshoe Falls and only a very small proportion of the flow of Niagara River passes over it. Any further development on the American side will be at the expense of the water passing over that fall and will mean a great impairing of its beauty. On the other hand, as the bulk of water passes over the Horseshoe or Canadian Falls, considerable development can still be done there, without in any way affecting the scenic beauty of either Fall, for the water taken at the Canadian side of the river cannot have any material effect on the American Fall.

If then the Government of Canada places a restriction on the development, it will mean giving up the tremendous advantage which the Canadian side of the river has by virtue of its location, over the American side, which, as has been shown, is at its limit with respect to development of power without materially injuring the American Fall.

No doubt legislation will soon be introduced into the House of Commons bearing on this point, and we as Canadians should see that we do not give up this great natural advantage at the request of the nation to the south of us. While it would be a mistake to issue wholesale charters for power development purposes, still with reasonable care a great amount of the water at present flowing over the Canadian Fall can be used to perform useful work and the natural beauties of the Falls at the same time be preserved.

WHAT WE ARE DOING

S. P. S. Electrical Club.

As is known by those interested in the welfare of this club, it is now in the second year of its life. Its chief aim is to give third and fourth students in mechanical and electrical engineering a chance to freely discuss, informally, engineering subjects of interest. Only those who have taken an active interest in the work done by this organization, or have taken part in such discussions, can fully appreciate its value. Anyone who wishes his views to bear weight must be able to present them in a clear and convincing manner and to be able to do this experience is necessary.

Another important function, and one much prized by the members, is the excursion held on Saturday mornings to the principal places of interest in the city and vicinity. These are taken on some Saturday convenient to the manufacturer or engineer in charge.

A short synopsis of the work done by this club since January 1st, 1908, will give a fair idea of its possibilities and the benefits derived by its members.

On January 23rd, C. H. Hutton, '07, read a very interesting paper on "Lightning Protective Apparatus," applied principally to transmission lines, showing by means of lantern slides several types of lightning arresters, explaining their peculiarities and respective merits.

On February 6th, the members were favored by a practical demonstration of "Wireless Telegraphy," by D. F. Keith, '07. The difficulties overcome by the most successful of the experimenters were pointed out and many of the resulting inventions explained. The use of wireless telegraphy in the commercial world to-day was shown and a good explanation given of the different systems in use at the present time.

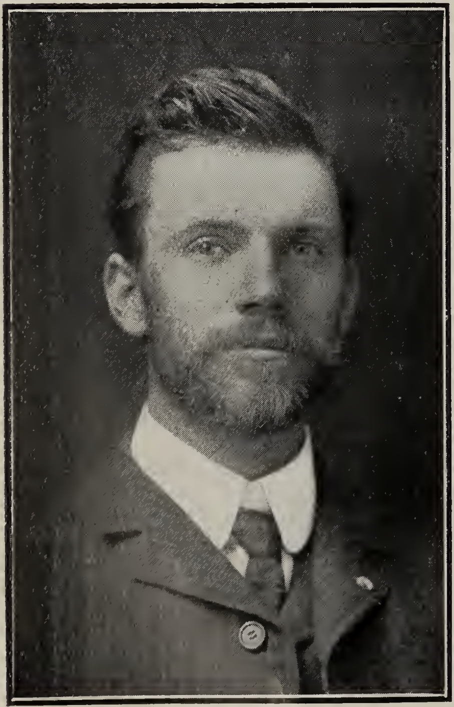
H. Coyne, '08, gave an interesting and practical paper on "The Induction Motor" on February 20th. Its construction was traced from the manufacture of the separate parts to the assembled machine, the paper being illustrated by many excellent slides. The different modes of winding, the different styles of connections, and the practical theory was given. The paper ended with an explanation of starting compensators and their use in connection with the induction motor.

Saturday morning, January 25th, the Scott and Terauley Street stations of the Toronto Electric Light Company were visited.

WHAT THE GRADUATES ARE DOING

On this page we shall be pleased to publish *professional* news of any of our graduates.

The graduates are again reminded that this is as much their organ as that of the undergraduates. A great number have as yet not sent in their subscriptions; we lose two cents in postage on every magazine sent through the mails on account of this. Post your subscription at once. The Engineering Society will have to meet a deficit of five or six hundred dollars on the publication as it is, so do not let there be any unnecessary waste of money.



Walter J. Francis, C.E.

Readers of "Applied Science" will be interested to learn of a recent change made by Mr. Walter J. Francis, C.E., one of the graduates of the School of Practical Science. Mr. Francis has severed his connection with the Dominion Engineering & Construction Co., Montreal, of which, since 1906, he has been chief engineer and assistant manager, to open an office for himself in the Sovereign Bank Building, Montreal, as consulting engineer. For two and a half years subsequent to graduation, Mr. Francis was employed as assistant engineer on the Union Station works, Toronto, leaving in 1896 to become draughtsman and designer for the Central Bridge & Engineering Co., Peterboro. This position he resigned in 1897 to undertake for the Dominion Government, the design of the Peterboro Lift Lock on the Trent Canal, the first of its kind in America. This led in 1900 to a promotion to Division Engineer and later to Engineer of Lift Locks, which position involved the design of a second lock at Kirkfield, Ont., as well as the completion of the Peterboro lock, then well under way. The magnitude of these undertakings and the ingenuity displayed in their design certainly place them among the interesting engineering works on this continent. On their completion in 1906, Mr. Francis resigned to take charge for Messrs. Ross & Holgate, of the construction of the 32,000 horse-power plant for the West Kootenay Power & Light Co. near Nelson, B.C. Returning to the east in the autumn of the same year, he connected himself with the Dominion Engineering & Construction Co. in the capacity indicated above. The World's Fair diploma that still hangs in the hallway on the second floor of the Engineering Building, was awarded for "remarkable excellence in topographical and architectural drawings" to two drawings, one of which was the work of Mr. Francis, then a student here. He graduated with honors in '93 and obtained the professional degree C. E. from the University of Toronto in 1900. In 1906 he captured the Gzowski medal, the gift of the Canadian Society of Civil Engineers, to the member submitting the best technical paper for the year. Mr. Francis is justly regarded as one of the brightest young men in the engineering profession in Canada. He is *par excellence* an expert on structural steel and concrete construction, and in this connection, his invitation by the Government Commission to examine the wreck of the Quebec Bridge and report thereon is significant. His experience during the past fifteen years has brought him face to face with almost all kinds of engineering problems. He is a member of the Canadian Society of Civil Engineers and of the American Society of Civil Engineers. We wish Mr. Francis every good fortune possible, and prophesy for him a career of growing usefulness and eminence.

We announce the formation of an engineering partnership between two of our old graduates, Herbert J. Bowman, '85, and A. W. Connor, '95. They will make a specialty of municipal and structural engineering, being the respective lines each has followed since graduation. Mr. Bowman is a member of the Canadian Society of Civil Engineers and an O.L.S. and a D.L.S. He was one of the founders of the Engineering Society. He has been practising as a municipal engineer in Berlin for twenty years, constructing a number of waterworks and sewerage systems and building many steel and concrete bridges. He has also been city and county engineer. He is a native of Berlin, being a son of the late I. D. Bowman, Esq., County Clerk and Treasurer. Mr. Connor is a double honor graduate in Arts, '93, and received the degree of C. E. in 1900. Upon graduation from the school he entered the service of the Hamilton Bridge Works Co., where he remained about six years. He was also with the Central Bridge Co. of Peterborough and the Canada Foundry Co. for about four years more. For the last three years he has been practising as a consulting structural engineer, being a member of the firm of Connor, Clark & Monds. He has designed many highway and railway bridges in steel and reinforced concrete, besides office and mill buildings and other structures. He is also an old Berlin boy, being the son of J. W. Connor, B.A., '64, for many years principal of the Berlin Collegiate Institute. The office of the firm is at 36 Toronto Street, Toronto, with a branch office at Berlin.

D. G. Park, '06, is with the Allis Chalmers Co., West Allis, Wisconsin.

The following graduates passed their O.L.S. exams.: H. W. Sutcliffe, J. L. Lang, F. W. Paulin, W. J. Moore, C. E. Bush.

T. R. Deacon, '91, is president and general manager of the Manitoba Iron Works, Limited, Winnipeg. He finds time to do a little consulting work. He was a member of the committee which recently brought in an exhaustive report on Winnipeg's water supply.

K. Rose and J. H. Chewett, both '88 men, are interested in the Evans Rotary Engine Co., Ltd., of Canada. They are having splendid success in placing their engines on the market.

C. W. Dill, '91, is senior partner of C. W. Dill & Co., engineers and contractors, Toronto.

C. A. Schofield, '07, is chemist at Niagara Frontier Laboratory, Buffalo.

W. J. Walker, '07, is a resident engineer on the C. N. Railway at Quebec.

A. W. Campbell, '06, is electrician with the Mond Nickel Co.

INFORMATION WANTED

We have been unable to verify the following addresses in the last year or so. Any information as to their present whereabouts would be greatly appreciated:

1885—J. F. Bleakley; E. E. Henderson.
1887—A. E. Lott; A. L. McCulloch; C. H. Pinhey.
1888—W. T. Ashbridge; D. B. Brown; J. Gibbons; B. Carey.
1889—G. F. Hanning; D. D. James.
1890—N. L. Garland; T. H. Wiggins.
1893—C. Forester; J. T. Laidlaw; F. L. Lash; A. L. McAllister; W. T. Main; W. Mines; R. Russell.
1894—H. F. Barker; A. E. Bergey; W. J. Herald; A. C. Johnston; J. E. Jones; A. L. McTaggart; C. J. Nicholson; R. T. Wright.
1895—W. M. Brodie; R. J. Campbell; H. S. Hull; H. L. McKinnon.

1896—J. A. McMurchy.

1897—W. A. B. Hicks; W. R. Smiley; M. B. Weekes; E. A. Weldon.

1898—J. E. Lavrock; D. Macintosh; A. E. Shipley; R. W. Smith; J. A. Stewart; H. L. Vercoe; T. A. Wilkinson.

1899—G. A. Clothier; C. Cooper; J. C. Elliott; W. E. Foreman; E. Guy; A. S. H. Pope; G. E. Revell; G. A. Saunders.

1900—J. H. Barley; J. E. Davison; G. W. Dickson; H. A. Dixon; J. C. Johnston; R. E. McArthur; S. M. Thorne; H. M. Weir.

1901—G. M. Bertram; J. T. Broughton; A. T. E. Hamer; F. C. Jackson; W. C. Lumbers; G. MacMillan; W. H. Stevenson

1902—J. M. Brown; W. G. Campbell; W. Christie; F. T. Conlon; H. V. Connor; W. M. Edwards; C. P. Henwood; D. M. Johnston; P. Mathison; R. S. Mennie; H. D. Robertson; H. J. Zahn.

1903—J. A. Beatty; R. E. George; J. G. Jackson; A. L. McNaughton; M. L. Miller; F. A. Moore; E. E. Mullins; J. P. Oliver; H. L. Seymour; J. Waldron; J. A. Welihan; N. D. Wilson.

1904—J. H. Alexander; T. D. Brown; J. W. Calder; C. A. Chilver; H. L. Chilver; P. C. Coates; S. E. Craig; J. G. Fleck; W. S. Gibson; J. P. Gordon; J. B. Heron; S. N. Hill; C. J. Ingles; P. V. Jermyn; O. B. McCuaig; G. G. McEwen; W. G. McFarlane; C. P. McGibbon; D. McMillan; E. E. Moore; J. Paris; J. Parke; F. W. Slater; W. J. Smither; D. T. Townsend; J. M. Weir.

1905—H. W. Arens; R. H. Armour; C. B. Aylesworth; G. G. Bell; J. C. Boeckh; A. V. Chase; T. E. Corrigan; M. C. Hendry; C. S. L. Hertzberg; W. G. Hewson; D. W. McKenzie; B. B. Patten; E. F. Pullen; G. L. Ramsey; R. B. Ross; H. V. Serson; D. L. N. Stewart; F. H. Sykes; W. E. Turner; J. M. Vaughan; H. L. Wagner.

1906—G. W. Bissett; M. E. Brian; A. Cameron; M. J. Carroll; A. L. Harkness; R. L. Harrison; S. Hett; W. C. Jepson; T. Jones; J. A. McKenzie; J. A. McPherson; D. W. Marrs; F. F. Montague; W. J. Moore; G. W. Paterson; R. E. Pettingill; W. K. Sanders.

1907—C. C. Rothwell; O. B. Bourne; G. H. Broughton; W. J. Bruce; G. A. Campbell; E. Cavell; A. C. Clendening; R. M. Coleman; C. B. B. Connell; G. P. Coulter; R. Davis; G. A. Dawson; J. S. Galletly; K. Hall; C. T. Hamilton; F. J. Hara; R. A. Hare; H. F. H. Hertzberg; L. W. Klingner; J. A. D. McCurdy; G. MacLeod; W. D. Mackenzie; H. V. Maynard; P. F. Morley; D. G. Munro; J. J. O'Sullivan; F. W. Paulin; H. A. Percy; F. E. Procknow; H. E. Rothwell; A. C. T. Sheppard; H. Southworth; G. S. Stewart; G. F. Summers; J. H. M. Wilkie; J. Young.

BOOK REVIEWS

The Electric Furnace, Its Evolution, Theory and Practice

ALFRED STANSFIELD, D. Sc.

Canadian Engineer, Publishers

This work originated, as the author remarks in the preface, in a series of papers written for the "Canadian Engineer," and is therefore intended to represent in a very simple manner, "the principles on which the construction and use of the electric furnace depend, and to give an account of its history and development."

The first chapter gives a historical review, and the second one is devoted to a description and classification of electric furnaces. In the third chapter the questions of efficiency and of relative cost of electrical and fuel heat are discussed in a way that is not only instructing but also very interesting.

The following table, taken from the work under consideration, gives the net efficiencies of furnaces used for melting metals:

	Per cent.
Crucible steel furnaces, fired with coke	2 — 3
Reverberatory furnaces, for melting metals ..	10 — 15
Regenerated open-hearth steel furnaces	20 — 30
Shaft furnaces (foundry, cupolas, etc.)	30 — 50
Large electrical furnaces	60 — 85

It is evident that the electric furnace is easily first in this respect, and this great advantage is often more than enough to offset the disadvantages from the lower cost of coal as compared with the equivalent amount of electrical energy. It is thus seen that the discussion of the relative cost of electrical and fuel heat for any process, must also involve considerations as to efficiency.

The fourth chapter is entitled "Electric Furnace Design, Construction and Operation." The temperature obtained in a furnace depends not only on the rate of supply of electrical energy, but also upon the rates of radiation and conduction of the heat of the furnace-walls. The temperature finally attained is therefore a point of equilibrium at which the rate of supply is equal to the rate of loss. As these losses are much greater in proportion to the energy consumed when small furnaces are used, the efficiency must increase as the capacity of the unit is increased. The study of the electric furnace in the future, from the point of view of avoiding losses by radiation and conduction, is bound to yield very profitable results.

The recent advances made in the methods of production of iron and steel in the electric furnace, forms the topic of the fifth and most important chapter in the book. The report of the Canadian Commission on European electro-thermic methods of iron and steel production, as well as the more recent report issued by Dr. Haanel on the experimental work at Sault Ste. Marie, have been fully consulted and the remarks made by the author are decidedly optimistic for the future of this industry.

The use of ferro-alloys has become very prominent in recent years, mainly because of their ease of manufacture in electric and crucible furnaces.

In chapter VI the author mentions the alloys with silicon, manganese, chronium, tungsten and vanadium. As the subject of carbide and carborundum furnaces has been exhaustively treated by other writers, a comparatively brief reference is made to these, and the main portion of the chapter is devoted to electro-thermic methods of producing zinc. Amongst other uses of the electric furnace are those for the production of phosphorus, carbon bisulphide, alunderm, caustic soda and aluminum.

"The future development of the electric furnace" forms the subject of the last chapter, and the remarks of the author are very optimistic. Greater efficiency combined with higher temperature are the great assets of this new scientific tool, and in the future as the coal-fields become exhausted, it is most probable that its use will become almost universal in thermal operations.

Regarding the book as a whole, it has been written in a very interesting style, and the "principles" emphasized by the author throughout the chapters are never hidden by too large an array of details, such as often obscure the main thought of many similar works. While not encroaching a great deal on the subject covered by Borchers' Electrometallurgy and Moissan's and Wright's works on the electric furnace, the present work forms a most useful addition to the literature on this topic.

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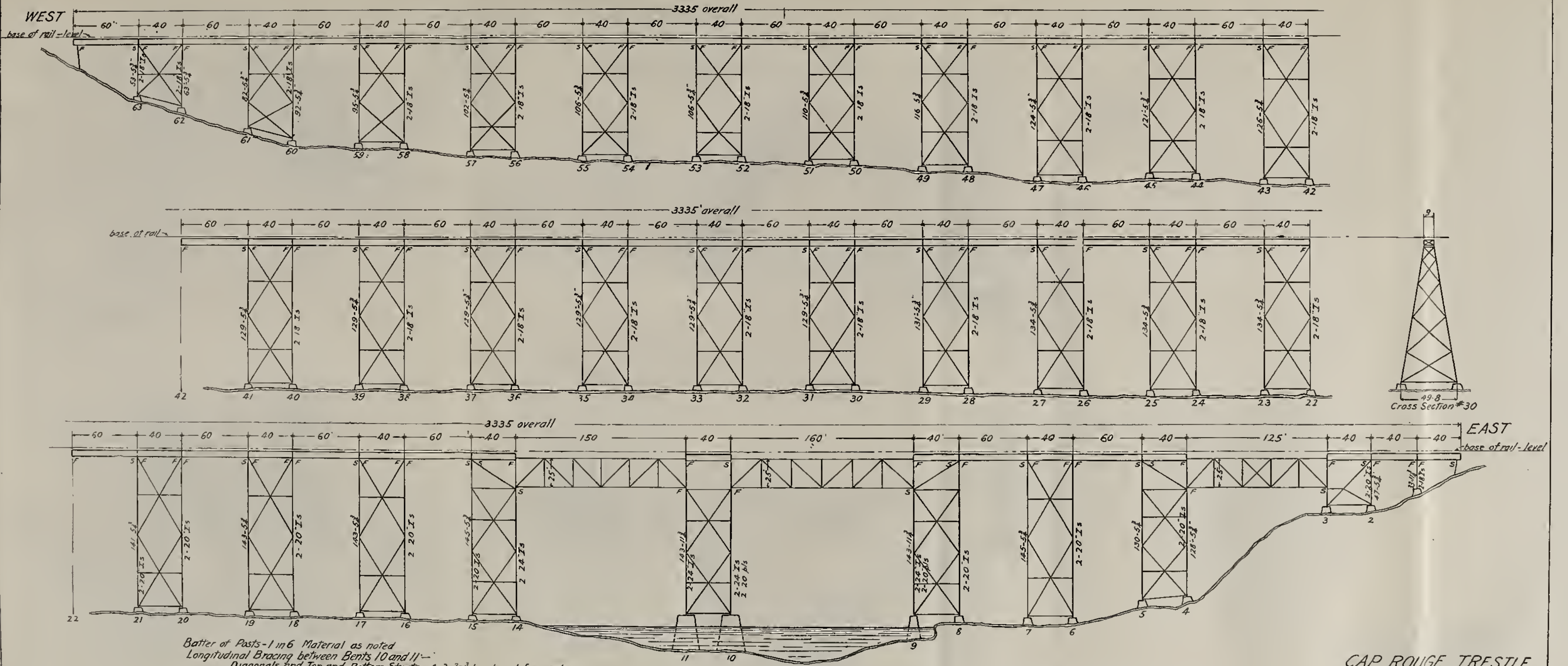


Batter of Posts - 1 in 6 Material as noted

Longitudinal Bracing between Bents 10 and 11 :—

Diagonals and Top and Bottom Struts - 4 3×3×⅜ Ls laced four sides

Intermediate Struts - 4-5×3×$\frac{5}{16}$ Ls, laced

Longitudinal Bracing elsewhere :—

Diagonals and Bottom Struts - 4-3×2½×⅜ Ls laced four sides.

Intermediate Struts - 4-5×3×$\frac{5}{16}$ Ls, laced

Sway Bracing :—

Top Struts, Bents 3, 4, 9, 10, 11, and 14 - 2-12" [s laced

Top Struts elsewhere - 2-10" [s laced

Diagonals and Bottom Struts - 4-3×2½×$\frac{5}{16}$ Ls, laced four sides

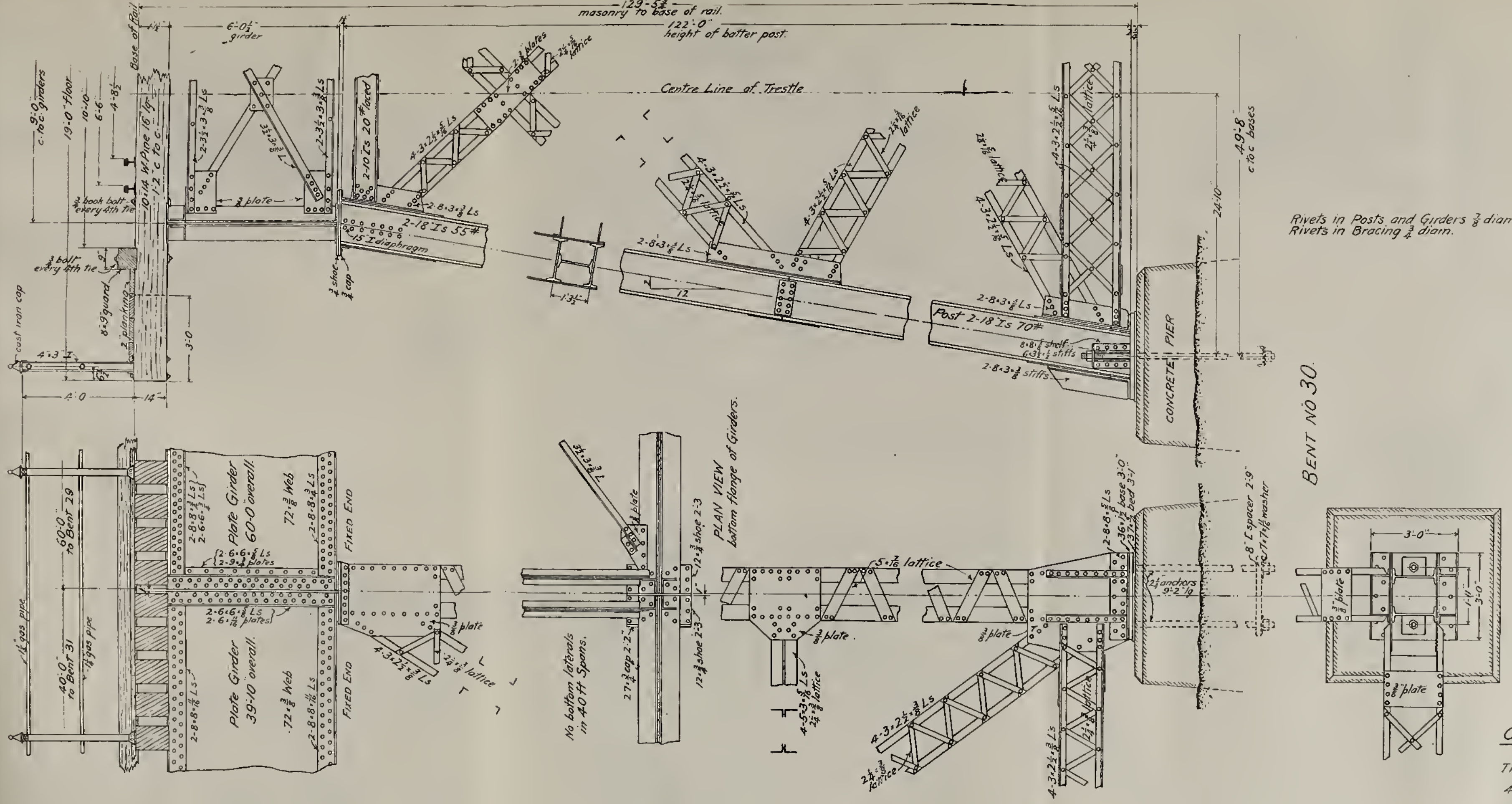
NOTE :- Fixed ends of spans marked "F"
Sliding ends marked "S"
Heights given denote distances from base of rail to masonry

CAP ROUGE TRESTLE

GENERAL DIAGRAM

FIG 1

Feb-08 D.C.T.



Rivets in Posts and Girders 7/8 diam.
Rivets in Bracing 3/4 diam.

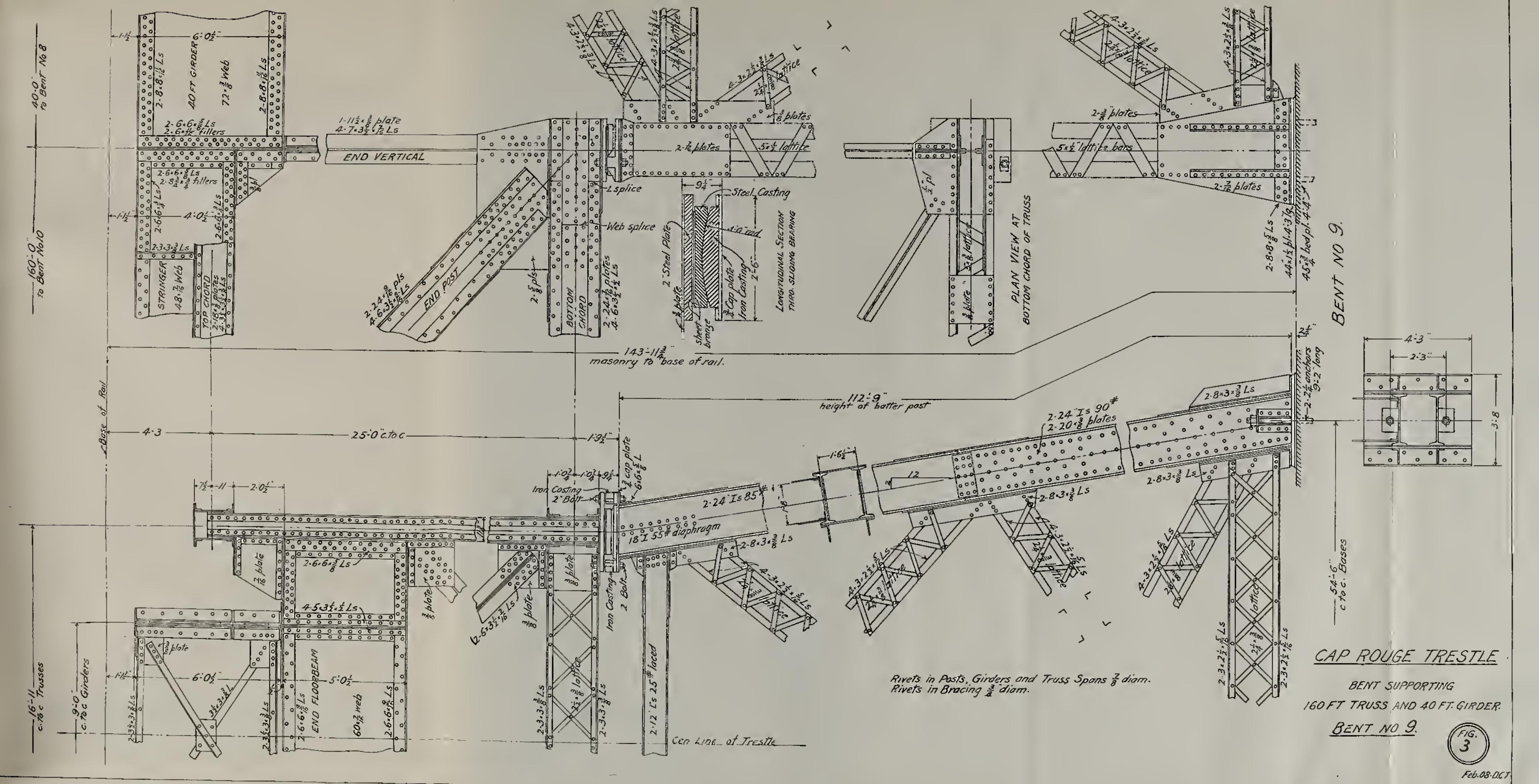
CAP ROUGE TRESTLE

TYPICAL BENT SUPPORTING
40 FT. AND 60 FT GIRDERS

BENT NO 30.

FIG. 2

Feb. 08 O.C.T.



Rivets in Posts, Girders and Truss Spans ⅞ diam.
Rivets in Bracing ¾ diam.

CAP ROUGE TRESTLE

BENT SUPPORTING
160 FT TRUSS AND 40 FT. GIRDER

BENT NO 9.

FIG. 3

Applied Science

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THE CAP ROUGE TRESTLE

D. C. TENNANT, B. A. Sc., '99.

Cap Rouge is a small town, situated at the mouth of Cap Rouge River, on the north shore of the St. Lawrence, about ten miles west of Quebec. The ravine formed by the mouth of Cap Rouge River is about three-quarters of a mile wide and two hundred feet deep and is fairly flat. The line of the National Transcontinental Railway from the Quebec Bridge westerly is to cross the mouth of the valley parallel to the St. Lawrence, the track being elevated about one hundred and fifty feet above the ground at the deepest part of the ravine. This necessitates a steel trestle. Preliminary plans were prepared and tenders called for by the Commissioners of the Transcontinental Railway at Ottawa. Messrs. M. Pond and J. T. Davies, of Ottawa, were awarded the contract for the substructure and the Dominion Bridge Co., of Montreal, the contract for the superstructure. Plans showing the proposed design were submitted by the Bridge Company with their tender.

The trestle was designed in accordance with Dominion Government specifications of 1905, using the live load class "heavy," which provides for two 180-ton locomotives, each 48 feet long, followed by a uniform load of 4,750 pounds per lineal foot of track. Allowance is made for impact and vibration by adding to the sum of the dead and live loads, an increment found by the formula.

$$\frac{LL^2}{DL + LL}$$

where $LL =$ the live load stress and $DL =$ the dead load stress, wind was taken at 30 pounds per square foot of exposed surface.

The line is single track, and where it crosses Cap Rouge valley it is level and on a tangent. As will be seen from the diagram, Fig. 1, the east slope of the ravine is abrupt and about six hundred and fifty feet from the east end of the trestle the line crosses the river, which at this point is over three hundred feet wide. From the river to the west side the ground is fairly level and the west slope of the ravine is gradual. The greater part of the track is supported on braced towers, forty feet, centre to centre of bents longitudinally. These towers support forty-foot girder spans directly over them and forming the longitudinal top strut of the towers, and intervening sixty-foot girder spans. At the eastern escarpment it was deemed advisable on account of the steep slope of the ground and consequent danger of foundations being washed away in spring time not to build any piers on the face of the slope, so a one hundred and twenty-five foot deck truss span was used, one end resting on a short bent at the top of the cliff and the other end on a long bent, with its base at the bottom. The building of piers in the river was found expensive, so a one hundred and sixty foot deck truss span and a one hundred and fifty foot span were used, the ends of these resting on bents. Thus only two river piers were necessary, one under each bent supporting truss spans as shown in Fig. 1. The bents are numbered beginning from the east end, this being the direction in which the line was chained. Bents number twelve and thirteen in the original design came in place between bents eleven and fourteen, but owing to difficulty in getting foundations, the design was changed, using a truss span, thus lessening the number of bents.

In this paper there is room for only a word about the foundations. The substratum is a shaley gravel and this is covered with a variable thickness of muddy clay—the kind that sticks. In the river bed there are also some layers of sand and silt. Considerable difficulty was experienced in obtaining a good foundation in the river and caisson work was finally used. In other places a solid foundation was easily available. All piers were built of concrete.

The bridge flooring is a modification of the ordinary Dominion Government floor and is shown in Fig. 2. On account of the height and length of the trestle it was thought best to lay a board walk on the ties outside the outer guard rail and to have a hand railing on the bridge. To this end the ties were made sixteen feet long and arranged to cantilever alternately on opposite sides of the bridge to carry the planking and the posts for railing. The ties are 10 x 14 inches, white pine, spaced 14 inches, centre to centre, longitudinally and notched one-half inch over the girders. The posts of the hand rail are spaced 9 feet 4 inches apart, one resting on every fourth projecting tie. The inner guard is an ordinary rail spiked to the ties and the outer guard is 8 x 9 inches, white pine, bolted to every fourth tie with 3-4 inch bolts. At four points on the trestle the deck and handrail are to have a side extension to allow for the stowing of a hand car in case it is overtaken by a train.

The 40-foot and 60-foot plate girders were made the same depth—6 feet 1-2 inch, back to back of flange angles. In order to avoid complications in clapping the ties no cover plates were used on the top flanges. The forty-foot girders were composed of 72 x 3-8 webs and 2-8 x 8 x $\frac{11}{16}$ angles in each flange. For sixty-foot girders the same size of web was used, the top flange being made of 2, 8 x 8 x 3-4 angles and 2, 6 x 6 x 3-4 angles as shown in Fig. 2, and the bottom flange of 2, 8 x 8 x 3-4 angles and 2, 17 inches x 9-16 inch cover plates. The girders were spaced 9 feet 0 inches apart, centre to centre, and connected across every twelve or thirteen feet by brace frames. The sixty-foot girder spans have both top and bottom lateral systems, but bottom laterals were omitted on the forty-foot spans. One end of each sixty-foot span is allowed to slide on top of the supporting bent, thus making an expansion joint every 100 feet as shown in Fig. 1.

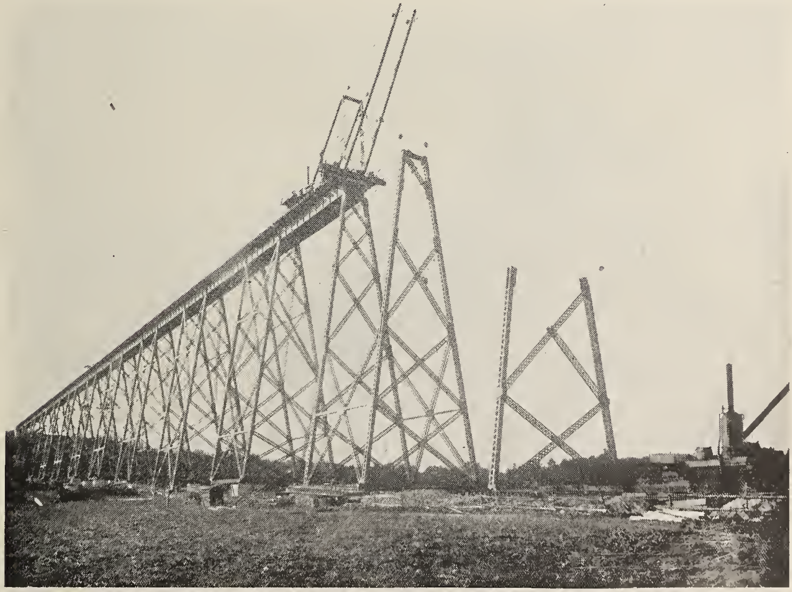

Fig. 4—Erection of Bents 41 and 42.

The 125-foot, 150-foot, and 160-foot truss spans are very similar in construction. For uniformity they were all made 25 feet deep, centre to centre, of chords. Some details of the end of the 160-foot span are shown in Fig. 3. It is made up of six panels each of 26 feet 8 inches. The trusses rest on the caps of bents 9 and 10 and carry between them the floorbeams, which support the stringers on their top flanges. The end floorbeam as indicated in Fig. 3, carries one end of the forty-foot girder span and so is stronger than the intermediate floorbeams and lower than them by the amount that the forty-foot girders are deeper than the stringers of the truss span. The truss spans have top and bottom laterals and at every panel point X bracing, the lateral wind force from the train and deck being resisted by the top lateral system and the resulting reaction at the ends of the truss being carried down through the end sway, bracing into the bents. Attention might be called to the bearings of the truss spans, the sliding bearing being shown in Fig. 3—a thick shoe plate on the bottom of the truss and two castings shaped to give a spherical bearing. At the sliding end two sheets of bronze are inserted between the shoe plate of the truss and the top casting, the sliding taking place between these two sheets. The truss is anchored to the bent with 2-inch bolts. This gives a simpler and more stable bearing than could be obtained by rollers—requiring less height.

The trestle posts were made of two 18-inch beams, two 20-inch beams, or two 24-inch beams, as indicated in Fig. 1—the details being shown in Figs. 2 and 3. These posts are stayed longitudinally and transversely at intervals not more than thirty-two feet apart by bracing composed of four angles latticed on four sides, as shown in Figs. 2 and 3. All trestle posts are given a batter of 1 in 6; the longitudinal bracing is therefore all in the same inclined plane, the distance, centre to centre, of trusses in the truss spans being made such that the posts of the supporting bents are in the same plane as those of the adjacent bents, carrying girder spans. The bents are anchored to the piers with anchors varying from 2 1-4 inches to 3 1-4 inches in diameter and from 7 feet 2 inches to 17 feet 7 inches long.

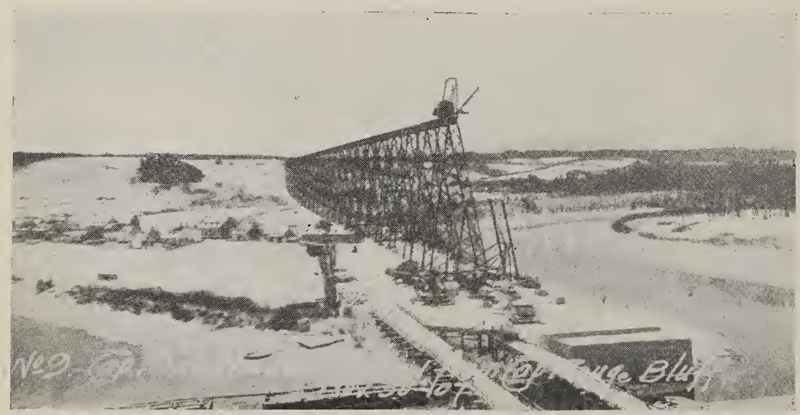

Fig. 5—From Bent 18 Westward.

Erection was begun from the west end in July of 1907 and in the fall, when the work was stopped for the winter, they had got as far as bent 18. The trestle is being erected with a two-boom derrick, travelling on the deck and handling the girders and upper sections of posts and bracing. The lower sections are handled by smaller derricks on the ground. It is proposed to erect the truss spans entirely with the derrick on the deck, using falsework. To facilitate this all splice plates on the chords of the trusses and all plates connecting to the web members are shop riveted to the chord sections on the west side of the splices.

Material was shipped from the works at Lachine entirely by scow, thus reducing cost of transportation to a minimum. As will be seen from the photograph, Fig. 5, Cap Rouge River takes a turn just on the north side of the trestle, running parallel to it for almost 1,000 feet, thus making it possible for a scow to be floated into the mouth of the river at high tide, across the line of the trestle, and upstream far enough to bring it about opposite bent 40, or about the centre of the length of the trestle. Here on the bank of the river a landing stage has been set up and all the material so far has been unloaded.

In conclusion, the writer desires to thank Mr. R. L. Uniacke, Bridge Engineer of the National Transcontinental Railway, for information and photographs kindly given, and the Dominion Bridge Company for access to drawings and other data in connection with the trestle.

FRENCH HYDRO-ELECTRIC POWER PLANTS IN THE VICINITY OF GRENOBLE

CHARLES H. MITCHELL, C.E.

M. Can. Soc. C.E.: M. Am. Soc. C.E.: A. Am. Inst. E.E.

As an especially notable example of the utmost development of mountain streams for power production, the writer has selected for presentation to the readers of "Applied Science" the region around Grenoble in Savoy. To realize the remarkable impetus given to manufacturers by the recent installations on these streams, one must actually visit for himself the several districts and note the completeness and various uses to which the electrical and mechanical power is put. The following descriptions were included in an illustrated address on the subject of European Power Development given by the writer before the Engineering Society of the University of Toronto not long since.* The illustrations shown were obtained by camera on personal visits to these plants during the year 1906.

The city of Grenoble lies in the heart of the French Alps. Its 70,000 people are engaged almost entirely in the manufacture of gloves and kindred leather industries, hats, buttons and clasps, linen and silk weaving, wood-working, paper, cement and miscellaneous iron manufactures. In earlier days, many of these industries were operated by small steam power units, and in the case of paper and cement, by direct water-power, at the waterfalls in the vicinity of the city.

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*These plants, along with numerous others in Central Europe, are described more at length by the writer in a series of articles in the "Canadian Engineer," which appeared during the year 1906.

We are indebted to Mr. Mitchell for use of the plates illustrating this article.

Since the advent of electrical transmission, however, the conditions have changed; now the numerous waterfalls are more advantageously developed and their power transmitted to the city and adjoining towns. Grenoble is situated at the junction of two small rivers, the Drac and its tributary the Isere, both rich in natural power. A few miles above the city, on the Drac, another tributary the Romanche enters, and this, notwithstanding its small size, is the most efficiently worked of the three. On these rivers and within thirty miles of Grenoble are now installed some sixteen hydro-electric and direct hydraulic plants, varying in capacity under normal conditions from 1,000 to 8,000 horsepower, and having an aggregate power of some 60,000 horsepower.

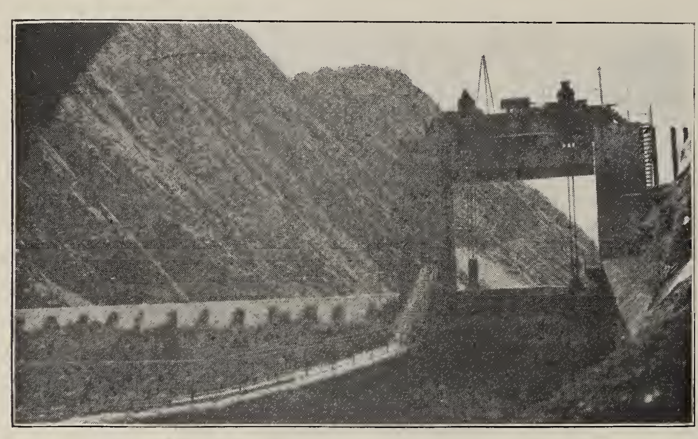


Fig. 1.—Avignonet Dam and Head Sluice.

Under these circumstances, it is not surprising that when a few years ago the French Government and the people took up the question of investigation of the water-powers and hydroelectric resources in the Alps, Grenoble was chosen as the headquarters and centre of operations of the Congress. The work of this body, known as the "Congress de la Houille Blanche," ("White Coal,") has now become world famous and its proceedings, bound in two large octavo volumes, form a most valuable engineering record, describing as they do in detail, the many plants then (1902) in operation and under construction.

The moving spirit of this congress was M. Berges, of Lancey, a small town in the valley of the Isere, about 10 miles north of Grenoble. He owned several mills utilizing water-power from mountain streams tributary to the Isere, aggregating about 6,000 horse-power; used mainly for pulp and paper manufacture, saw mills, etc., as well as lighting and traction purposes. That he is a pioneer is evident from the fact that as early as 1868, he built the first conduit down the mountain and established a plant at Lancey, under a head of some 600 feet. A few years later, he increased this to 1,600 ft. head, using about 18 cubic ft. of water per second. This plant has continued in operation to the present time with but little trouble from the high head. A second installation here of about 2,000 ft. head remained until a few years ago the highest operated head in the world.

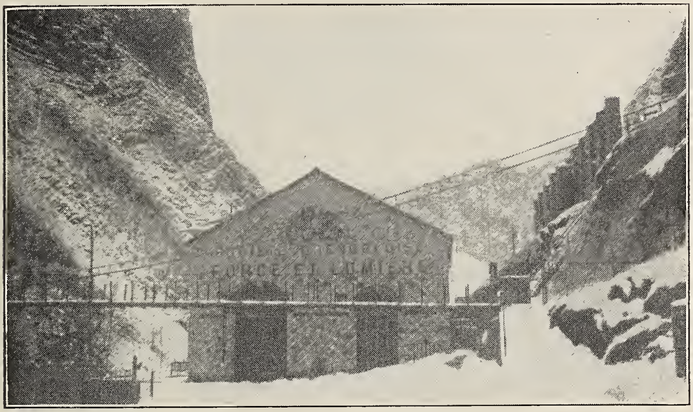


Fig. 2.—Avignonet Generating Station.

It is, of course, impossible in this article to adequately describe the many plants in the vicinity of Grenoble. Several of the more interesting installations are selected as typical of the district in which they are located.

AVIGNONET STATION, DRAC RIVER.

The Drac River drains a large area in the higher Alps and flows to the Rhone. Its dry weather flow in midwinter is fed only by springs, and above its junction with the Romanche does not exceed 800 cubic ft. per second. At times of freshet, however, this discharge runs up to the enormous flood of 40,000 cubic ft., a ratio of 1:50, which is most unusual.

The uppermost plant on this river at present is that of Avignonet, situated in a deep and narrow gorge about 25 miles above Grenoble. It is one of three plants owned by "La Societe Grenobloise de Force et Lumiere," and has an output under normal conditions of about 6,000 horse-power. The power is used in Grenoble for street railways and miscellaneous industries, for mines at La Mure, 8 miles away, and for factories at Bourgoin, 60 miles distant.

The general scheme of the plant is that of a dam in the gorge about 3,000 ft. above the station; a tunnel in rock, a forebay cut in the rocky cliff; and penstocks to a generating station in the bed of the gorge; the hydraulic units operating under about 80 ft. head.

The dam is a heavy concrete structure of the over-fall type, with a total height of about 65 ft., having exposed faces lined with masonry. On one side is a sluice way closed by a Stony gate, about 25 ft. wide by 20 ft. deep. (See Fig. 1.) The dam is seldom over-topped by floods, the regulation being effected by the Stony gate. In front and shoreward of the sluice is the intake, with screens and headgates opening to head race, and being a tunnel, is protected from rock slides, and has a carrying capacity of about 1,400 cubic ft. per second. This tunnel has an overflow regulating weir which discharges into the river at about 200 yards above the station.

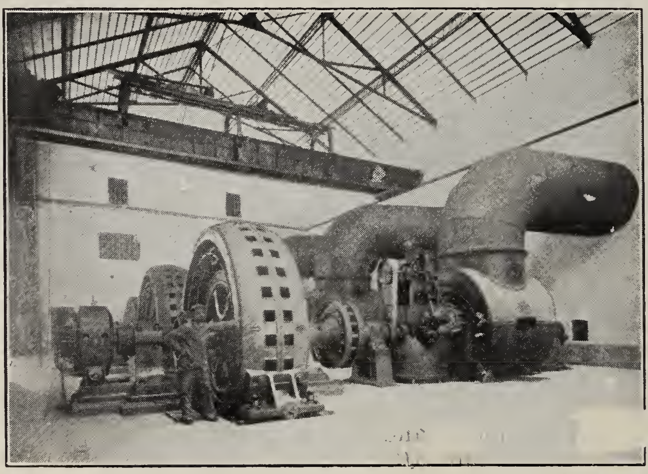


Fig. 3.—Interior of Avignonet Station.

The tunnel terminates in a forebay formed in the cliff by excavation and heavy masonry walls, provided with an adjustable weir and spill, and with separate screens and sluice gates to each penstock. The penstocks—five in number, with provision for two more—are 7 ft. diameter, and are fitted with 4 ft. diameter breathers below the sluice gates. See Fig. 2, in which may be also noticed a light suspension bridge crossing the river at this point.

The generating station is a heavy stone structure, equipped with five units, each of about 1,200 horse-power electrical output, with horizontal shaft, direct connected, at 250 R.P.M. The turbines are double "American" type, built by Piccard Pictet & Co., of Geneva, and are fitted with oil pressure governors, which appear to give good regulation. The generators are by Schneider

& Co., of Creusot, 3 phase—the latter being 15,000 volts. Three original units installed in 1901 were formerly wound to 26,000 volts, and intended to operate directly on the line without transformers; but these were found unsatisfactory, hence were rebuilt for 15,000 volts. The transformers are 15,000 to 26,000 volts, air cooled. The interior of the station is shown in Fig. 3.

The transmission line is interesting from the fact that the portion nearer to Grenoble is used jointly by this and another company (Champ Station, described below). The line from Avignonet to Grenoble consists of three circuits carried on iron poles. The towers for the joint transmission line shown on the right hand of Fig. 4, are about 40 ft. high above ground, and carry six circuits of 26,000 volts. These towers are set 6 ft. in the ground in concrete, the cross arms are wood, 10 ft. long, set in an iron framework, and each tower costs, complete, $100. At the junction with the second company, about 8 miles above Grenoble, a special structure (Fig. 4) is erected, and similar ones are also used in the city. Each company has its respective side and interconnecting and sectional switches. The two companies work in harmony, one using the other's wires at times for repair on the other side of the tower.

The snow seen in the accompanying pictures, while common, is unusual to such an extent in this locality. There is no trouble from floating or frazil ice, however, in any of the power plants in the vicinity of Grenoble.

CHAMP INSTALLATION, DRAC RIVER.

The Champ Station is situated near a village of the same name, and is about 8 miles above Grenoble, at the junction of the Romanche River. It is owned and operated by the Fure & Morge [illegible] Grenoble, and under normal conditions of river has an output of about [illegible],000 horse-power, which is used for miscellaneous factory power in and near Grenoble. There are upwards of 70 works now connected through about 15 receiving stations. It was first operated in 1902.

The general scheme is quite different from the plant at Avignonet, owing to the nature of the river at this point, which is shallow and flows through a gravel bottom in a wide valley. The intake works are situated about 3 miles up stream and the water is conveyed to the generating station by means of a flume laid underground; the station stands in the flat bed of the valley and the water is discharged through a short canal into the river channel near by.

The intake consists of a submerged dam at right angles to the stream, terminating near the shore, in an intake set parallel to the stream, consisting of submerged arches provided with gratings and sluices. Special precautions were required in this respect to prevent entrance of debris, gravel and stones, of which the river carries considerable. Behind the intake is a headbay

1,900 feet long, acting as a settling basin and provided with overflows having adjustable crests. At the end is a bell-mouthed entrance to the flume, fitted with a gate having an air inlet behind.

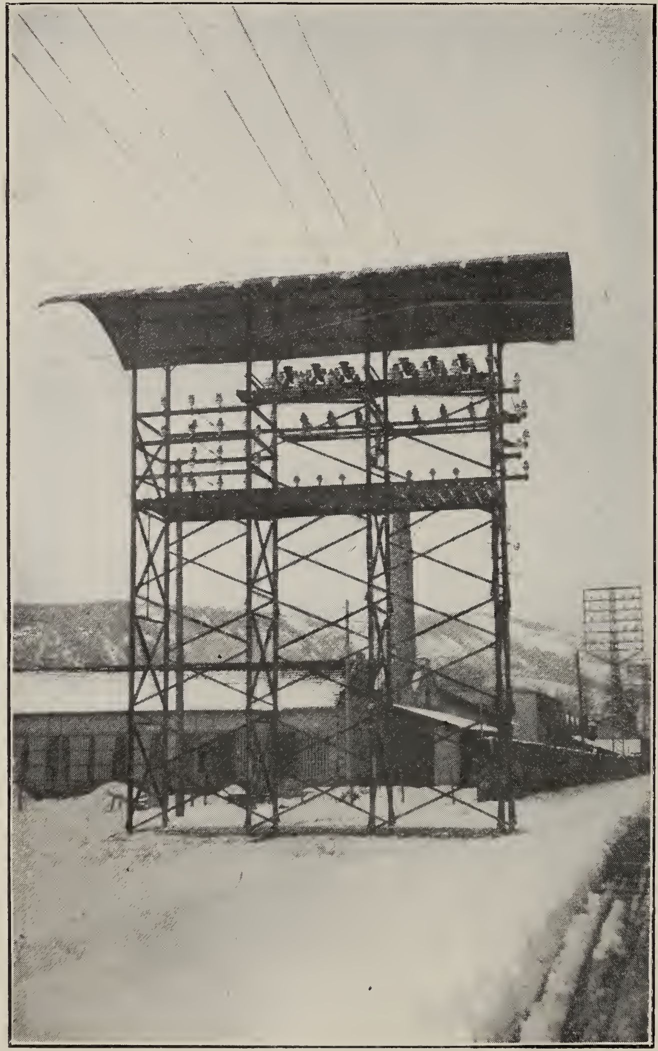


Fig. 4.—Junction Tower, Transmission Line.

This flume is a most interesting work, about 14,000 ft. long, 10 ft. 8 in. interior diameter, laid on a grade to conform to the slope of the river, partly in trench cut, and then filled over with gravel and earth. Its carrying capacity is figured at about 800 cubic ft. per second at a speed of 10 ft. per second. The upper 6,000 ft. being under light pressure, is of concrete reinforced with steel rods. The girth rods, a few inches apart, vary from ½ to 1 in. diameter, and the longitudinal ones from ¼ to ½ in. The whole thickness of shell varies from about ⅞ to 1¼ in. The remainder of the flume is of steel plate from ⅜ to ⅝ in. thick, and the structure throughout rests on a concrete foundation about 12 in. thick. There are three air shafts or breathers carried above the head level about 4 ft. diameter, along the length, to provide

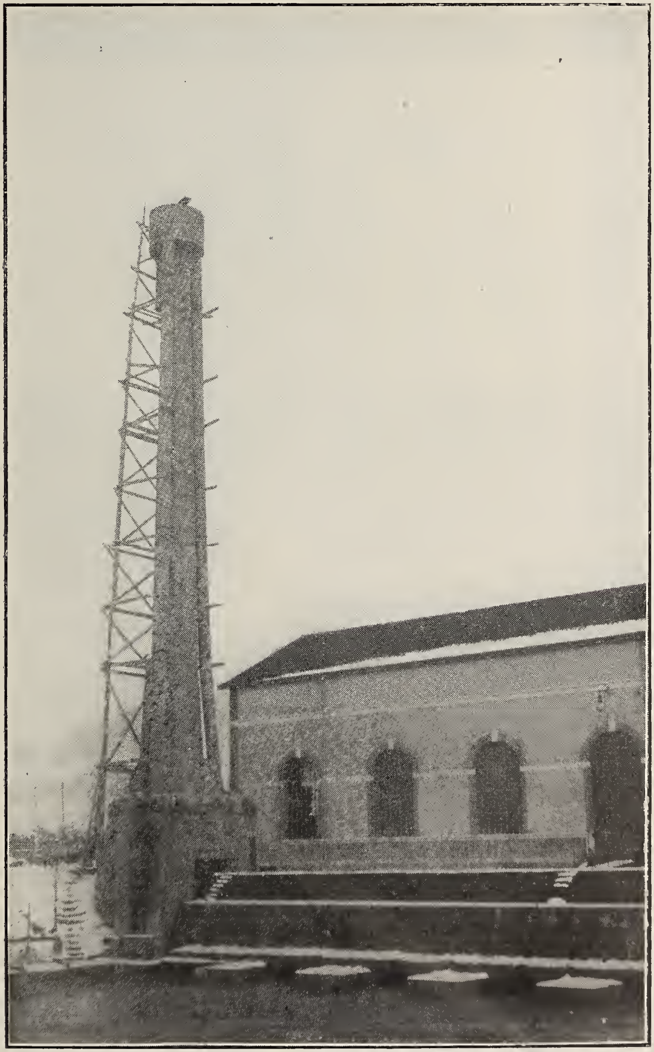


Fig. 5.—Terminal Overflow Pipe, Champ Station.

against entrained air or collapse when emptying. The most interesting feature of this flume is the terminal air shaft at the generating station, which consists of a vertical prolongation of the steel flume after the penstocks are taken off leading to the turbines. The vertical shaft converges from the 10 ft. diameter to about 5 ft. at the top, a total height above tail water of about 140 ft. The top terminates in an open chamber drained by three down pipes 18 in. diameter leading to outlets in the tail race. The water stands up to about 116 ft. above tail level when the plant is not operating, but when running full load this becomes 100 ft., which is the working head, the difference being friction and entry losses.

Referring to Fig. 5, showing the stand pipe relief, a scaffold for repairs will be seen. It may be interesting to note that about three weeks before the writer's visit on February 13th, 1906, the upper part of the pipe collapsed from a singular cause. A few days of cold weather caused ice to form near the top with the water at a high level. Subsequently, when the water lowered suddenly, a vacuum was formed resulting in the crushing of the thin steel shell for about 20 ft. from the top. While this accident might happen in Canada, it is considered as a very unusual occurrence here.

The turbines, five in number, are supplied by short horizontal penstocks connecting with the main flume, fitted with butterfly valves. They were built by Neyret-Brenier & Co., Grenoble, and are single wheels on horizontal shafts with cylinder gates, operating at 300 R.P.M. giving 1,500 horse-power. Though several wheels are fitted with simple governors they are regulated by hand, and appear to be fairly steady. In addition to the stand pipe relief, there are automatic relief valves on each turbine, which are also fitted with hydraulic servo-motors operating the distributors and compensating valves, thus shunting the turbines and maintaining a nearly constant flow in the main flume. The attendants say that the normal variation in level in the standpipe when operating is about 6 inches.

The generators are by Brown Boveri & Co., of Baden, 1,000 k.w. revolving field 3,000 volts, direct connected, and with the switchboard and transformers from 3,000 to 26,000 volts, present no especial features. The transmission lines are described above.

GAVET STATION, ROMANCHE RIVER.

The Romanche River has distinctive features which are remarkable. Its flow is very small, in dry weather being only about 300 cubic ft.; normal for about 9 months about 700 cubic ft., and flood discharge about 6,000 to 9,000 cubic ft. per second. Its descent is very rapid, hence high heads are the rule in the seven plants situated within the 12 miles of its course. These plants aggregate nearly 40,000 horse-power, and are used for various purposes; mainly in electro-chemical industry. There are several carbide of calcium works, and at Livet, 24 miles from Grenoble, is the celebrated electric steel works of Keller Leleux & Co. At Livet is located also the municipal plant, generating light and power current for Grenoble. The transmission line of the latter is unique, for it is constructed with wood-concrete poles, that is, thin straight cedar poles encased in an envelope of concrete from 1 to 2 in. thick, which in the three years of operation appear to have given entire satisfaction. A careful examination of these revealed no serious cracks and it has occurred to the writer they might be tried with success in Canada, notwithstanding the cold weather conditions.

The Gavet Station, just completed, is situated about 8 miles above the Champ Station, or 16 miles from Grenoble. It also is owned by the Societe Grenobloise de Force et Lumiere, and commenced operations about March 1st, 1906. There are now three units installed, with a total output of about 5,000 horsepower, and provision for doubling this capacity. The low water period of the river, however (about three months) gives only about this amount. The power will be used for manufacturing, both mechanical and chemical.

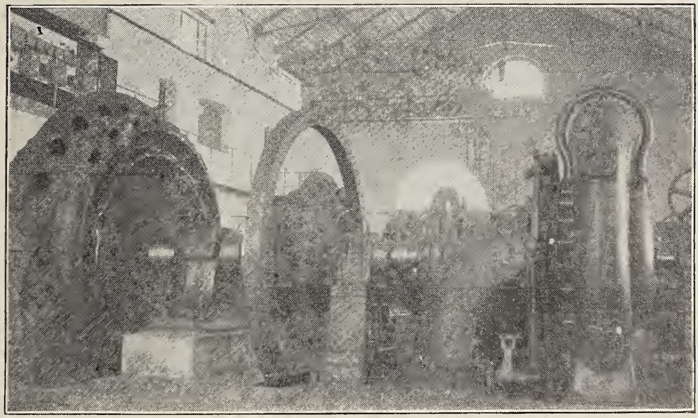


Fig. 6.—Interior Gavet Station.

The headworks are very ingenious, and a type of all plants on this river, which floods quickly and carries large quantities of gravel, etc. The head dam consists of piers and buttresses carrying two steel Stony gates (counter-balanced), each about 30 ft. wide and 12 ft. deep, capable of being operated by hand by one man. In front of the dam is a weir parallel to the stream, with its crest about 2 ft. below the top of the gates; behind this is a settling basin having a sluice at the lower end and having a second similar weir on its opposite side. Water, after passing the first two weirs, enters a second elongated basin, having, at the lower end, a third sluice, and, in the side, the head screens leading to the head race, which is provided with a simple gate about 12 ft. wide, 10 ft. deep. This scheme offers two Stony and two secondary sluices for normal flood water and permits the passage of abnormal floods over the whole; at the same time it provides settling or catchment basins for gravel. The flume to the generating station consists of a tunnel driven in the rock cliff about 10 ft. square and 7,000 ft. long.

The tunnel terminates in a small covered forebay high up the face of the cliff above the station, having outlets for two penstocks and one spillway. The penstocks—one of which is now installed—follow down the cliff, and are 7 ft. diameter by about 500 ft. long, and each branches to the three main and two exciter units at the rear wall of the station.

The station is of rubble stone, having a generating room, commodious switch-board gallery, wire ducts, transformer and arrester rooms. The writer had the pleasure of visiting the plant on February 14th with the consulting engineer, M. Boissonas, of Geneva, who pointed out many of the new features. On this occasion the units were started on their first long run, for the purpose of drying out the generators and transformers.

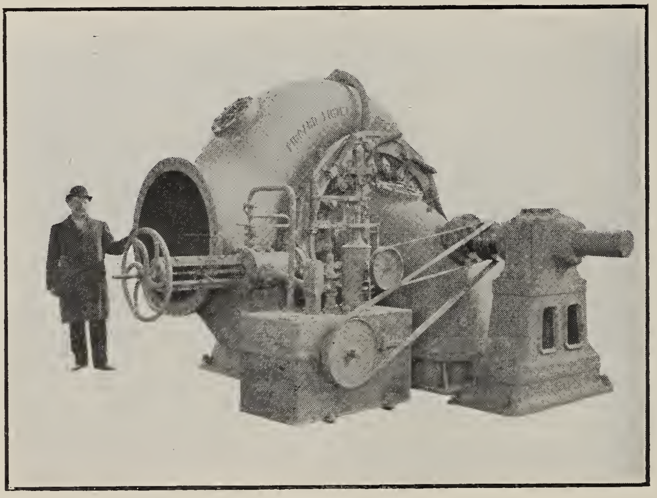


Fig. 7.—Gavet; 2,000-H.P. Turbine.

Each turbine develops 2,000 horse-power working under a head of 190 ft., and they are of the horizontal shaft, single spiral Francis type, built by Piccard Pictet & Co., of Geneva. The distributor gates are swivel style, with an actuating gate ring carried on arms fitted with springs, to positively take up lost motion. The governors are by the same makers, arranged with a new device on the fly balls, to stop petty vibrations. The main shafts have fly wheels (see Fig. 6) and Zodel flexible leather link couplings.

The generators are by Schneider & Co., Champagne, revolving field type, three phase, 4,000 volts, 231 amp. per phase. The transformers step up to 26,000 line voltage the same as at Avignonet, with which this station will at times be run in parallel, 24 miles distant. The line is at present carried on wooden poles.

POWER PRICES IN GRENOBLE.

Good quality steam coal in Grenoble costs about $5 per ton. The two power companies in the field sell for about the same prices. Those of the Societe Grenobloise are, in general, as follows:— For 24 hours service the average prices (variable on account of distance) are, say for 100 horse-power, $30 per horse-power year, and for 500 horse-power about $26 per horse-power year. In 500 horse-power quantities prices run down as low as $18 for transmitted power and even to $12 at the station. This company has now 15-year contracts for about 15,000 horse-power, with some customers 100 miles distant (by line). In the case of the Champ Company selling upwards of 4,000 horse-power, the average price per horse-power of the output is about $25 on a 12-hour day and $30 on a 24-hour day. Lighting current, sold in Grenoble by the city plant, costs about 12 cents per k.w hour.

THE MAPLE CREEK WATER SYSTEM

GEORGE T. CLARKE, '06.

GENERAL CONDITIONS.

The conveniences of a public water supply for villages, towns and cities are too well known to need any argument in their favor. There are four chief conditions which such supplies should fulfill in order to adequately meet the requirements of the community in whose behalf they are constructed and operated. First, the water supply should be wholesome and adapted to all domestic uses. Second, the supply should be abundant. Third, it should be delivered under a sufficient pressure. Fourth, it should be furnished at a cheap rate to the consumer.

Regarding the first named requisite without entering into conclusive statistics, which prove the statement, it will suffice to assert that the introduction of a wholesome public supply of water has invariably exercised a beneficial effect upon the death rate and general health of the community using it. Particularly is this the case regarding diseases of the typhoid and typho-malarial classes and it must be observed that in studying the sanitary conditions of any community not only the death rate, but the general health enjoyed by such community should be taken into consideration. Generally the one is an index of the other.

Regarding the abundance of the supply, water is needed for many purposes in towns and cities, both public and private. Public services comprise a fire supply, street sprinkling, the flushing of sewers, public fountains, etc. Private services comprise the water needed for drinking, cooking, washing, bathing, lawn sprinkling, etc.

In the early days of the general introduction of water supplies it was customary to itemize all these various services, alloting so many gallons for each and taking the sum total. At present, with all the experience of the past to guide us, it is found that they may all be combined in a general per capita allowance and in making the count of the number of inhabitants to be supplied, it is necessary to forecast the probable growth of the town, providing for the prospective needs of the community for the next twenty-five years at least.

The third consideration and a very important one is that of pressure. Most towns cover a territory more or less varied as to elevation. A great difference in level in the different parts of a town makes the problem somewhat complicated, because the pressure sufficient to carry water to the most elevated district will be embarrassingly great in the lower ones and consequently it is frequently necessary to reduce the pressure in the house connections in the latter case.

On the other hand it is frequently necessary to have a separate high pressure system to reach the more elevated portions of the town. This is generally accomplished by pumping into a small distributing reservoir. This necessitates an independent system of mains.

The great advantage of a high pressure at the hydrants is in connection with the fire service. Frequently if the pressure is high, streams may be got upon a fire by merely connecting the hose with the hydrants.

The water rate naturally must be sufficiently large to at least cover the expenses of the water supply, these expenses consisting of interest on the cost of the work, depreciation of the plant, and expenses of the operation and maintainance. Therefore the works should be built and operated with the greatest economy and from the start all unnecessary loss from waste and leakage should be reduced to a minimum.

SOURCES OF SUPPLY.

All the water supply of the earth is derived primarily from the water which falls on its surface. This deposit disappears in four different ways, evaporation, absorption by plant life, by running off as surface water and by percolation through the ground. The latter is termed ground water and of this class the purest and most desirable for public water supply is that obtained from springs.

The comparatively close proximity of never failing springs with an abundant supply, combined with other advantageous conditions made it possible for the town of Maple Creek, Saskatchewan, to install a public water system at a moderate cost. The Cypress Hills, a few miles to the south, form a very large water shed. Owing to the altitude of these hills the deposit of moisture is considerably in excess of that on the surrounding prairie and at the same time the evaporation is much less, owing to the hills being heavily wooded. Consequently there is a proportionately large amount of ground water, percolating through the soil until it strikes some seam of gravel or other loose formation, reappears in the foothills at many different points in the form of springs.

The series of springs selected by the town's consulting engineers is distant approximately eight miles from the corporation limits. These springs have an output of five hundred thousand gallons per twenty-four hours, and this flow has remained practically constant for the past twenty-five years at least.

The spring is located at the head of a small valley and the proposition was considered of building a dam across this valley, thereby forming a natural reservoir. However, under local prevailing conditions in that locality spring waters when stored in open reservoirs undergo changes which greatly impair their quality. The bright light and long hours of sunshine are particularly favorable to the growth of Algae and other vegetable organisms. These growths give the water a bad odor and taste, particularly in the summer season. Owing to these conditions it was decided to accept the other alternative and substitute for the dam a covered, reinforced concrete, compensating and storage basin. This alternative did not provide for storing as large an amount of water. But as the total supply was much in excess of the demand, an efficient service was given by the smaller reservoir, besides the great advantage of keeping the water clean and palatable at all seasons. This, in the opinion of the engineers, outweighed the advantage of larger storage.

The second advantage was gained by the compensating nature of the smaller basin, for by placing it nearer the town the pressure on the distributing system was diminished and at the same time the delivery was increased.

The springs themselves were carefully developed, so as to obtain the maximum flow. Then mains of vitrified pipe collect the water and conduct it to a small intake chamber. The system then consists of:—

1 The collecting mains.

2 The intake chamber.

3 A 10-inch wood main from the intake chamber to the storage basin.

4 The storage basin.

5 A 12-inch wood main from the storage basin to the distribution system.

6 The wood distribution system, including valves, hydrants and all appurtenances.

The difference in elevation between the intake chamber and the compensating reservoir is 37 feet, and the distance between them is 4,000 feet. Hence the 10-inch pipe is sufficiently large to conduct all the water from the springs to the reservoir.

The reservoir itself, which will hold two hundred thousand U.S. gallons, is provided with overflows, which conduct the excess water back into the creek. The difference in elevation between the town and the reservoir is 230 feet, making the static pressure on the distribution system practically 100 pounds. The town site is very even in elevation and consequently this pressure is practically constant over the whole system, and while it is a little high for domestic uses, yet it affords an excellent fire protection, and as we have previously stated this is a very important consideration in the installation of a public water supply.

Hence we see that in three respects, at least, the Maple Creek system conforms with the required conditions, namely:—

1 The supply is wholesome, as shown by the analysis of the water.

2 The supply is more than abundant for a town of 1,000 population.

3 It is delivered under a pressure not too great for domestic use, but great enough for fire protection.

On account of the fact that wood pipe is comparatively little used in Eastern Canada, it would probably not be inopportune to give a short description of it. Wood pipe is made from the best quality of kiln-dried Douglas fir, or Canadian white pine, free from knots, shakes and other imperfections. It is constructed of staves approximately an inch thick and two and a half inches wide, each stave being part of the circumference of a circle. The staves are made with tongues and grooves and after being placed in position are wrapped spirally under tension with drawn steel wire, or flat steel bands, the size of this wire or band and the spacing of it depending entirely on the pressure which the pipe has to stand. It is then dipped in a boiled asphalture compound at 300 degrees F., the object of this being to protect the wire against being destroyed by the chemicals in the earth.

The joints are made by simply driving the pipes together with a maul or ram. The efficiency of this wood pipe joint as it is at present manufactured seems to depend entirely on whether or not the wood, when water-soaked, will swell sufficiently to completely fill up the spaces between the spigot end and the coupling. Practically all the leaks in wood pipe are at the joint and when due care is not taken, and sometimes in spite of the best of care these leaks are frequent. This is a very great disadvantage to wood pipe. Another disadvantage in wood pipe is that it is not as adaptable for use in distribution systems, because the necessity for tapping these mains for house connection exposes the banding or wrapping to possible damage, both to coating and metal and thus deterioration begins.

There are three advantages claimed by some on behalf of wood pipe over cast-iron pipe.

These are:—1st The initial cost is decidedly less .
2nd There is no possiblity of destruction by electrolysis.
3rd The interior of the pipe does not suffer deterioration with age, if anything the friction factor decreases.

The third advantage named above affects directly the carrying capacities of the pipes. This carrying capacity has been determined with more or less accuracy by experiments made by many scientific investigators and covering many actual and supposed conditions. In reducing these experiments to a formula for ready use a value has been given to the roughness of the wetted surface of the conduit, the rougher the wetted surface, the less the capacity of the pipe. The value of "*F*," (representing the roughness) has been found to vary from 0.0115 for new cast-iron pipe, to 0.020 for tuberculated pipe; from 0.0115 for new steel riveted pipe to 0.017 for steel pipe in use for 14 years and from 0.011 for new wood stave pipe to 0.0096 for wood stave pipe in use for 10 years.

In every recorded experiment made to ascertain the carrying capacity of iron and steel which has been in use for a number of years, it was ascertained that the value of "*F*" had largely increased, whereas experiments upon old wood stave pipe have shown the reverse. The cause of the diminished capacity of the iron and steel is the gradual formation of nodules of rust or tubercles and the accretion of various organic growths on the inner surface of the metal. On the other hand, where a wood pipe has been kept full of running water, its inner surface becomes smoother with use.

Mr. Arthur L. Adams, a leading hydraulic engineer of the Pacific Coast, in a paper presented to the American Society of Civil Engineers, says:—"Clean cast-iron pipe would seem to have about 90 per cent. of the carrying capacity of a wood stave pipe, while, if seriously tuberculated, they discharge only about 66 per cent. as much as wood stave pipe of the same size. Clean steel pipe discharges 93 per cent. as much as wood stave pipe, while if tuberculated to an extent, which may easily occur in ten to fifteen years' use, these discharges may fall to 74 per cent. as much as wood stave pipe."

Omitting other considerations, is not the value of a pipe line investment porportional to its delivering capacity? Do not these percentages, then, represent approximately the relative value of these different classes of pipe as an investment.

The following table is submitted, based on six per cent. interest compounded annually on the difference between the cost of furnishing and laying cast-iron and wood stave pipe, exclusive of trenching. Prices stated are approximate only:—

Size	Wood	Cast Iron	Difference in Cost	Interest on difference in cost will re-build wood in
12-inch	$0 82	$1 64	$0 82	11.4 years
24-inch	1 65	4 61	2 96	7.6 years
36-inch	2 72	8 88	6 16	6.3 years
48-inch	4 25	14 00	9 75	6.2 years

Regarding the durability of wood pipe, under the usual conditions, it is conceded by those familiar with the subject that the life of wood stave pipe depends on two things. First, the necessity of keeping the pipe under such pressure as will thoroughly saturate the wooden shell. Second, the life of the iron or steel bands surrounding the staves.

Some examples of the durability of wood pipe as at present manufactured are here given. In 1862 the City of Victoria laid a distribution system of wood stave pipe, which was in constant and successful use until 1901, when they were removed to give way to pipes of larger capacity. In 1856 Elmira, N. Y., laid wood stave pipe, several miles of which are still in use under pressure ranging from 35 to 70 pounds. The water supply mains for Denver, Col., consist of over 100 miles of wood stave pipe, many miles of which have been in continuous use under high pressure for over 20 years without apparent diminution in service.

There have, no doubt, been failures in wood stave pipe, as there have been also in cast-iron and steel pipe, due to an unfamiliarity with the principles involved in their uses and it is for the competent hydraulic engineer, who is familiar with all three classes of pipe to determine that which should be used in each case.

ESTIMATED COST PRICES

I. Supply Main:

Material	Total Cost		Average Cost Per Lin. Foot	
Wood Pipe	$23,365 27		0.59½	
Valves and Specials	999 48		0.02½	
Labor				
Trenching	11,592 02		0.29½	
Pipe Laying	1,375 32		0 03½	
Tamping and Backfilling	1,178 85		0.03	
	————	$38,710 94	———	0.98

II. Distribution System :

Material			
Pipe	$6,879 18		$0.42
Special Valves and Hydrants	3,767 17		0.23
Labor			
Trenching	4,094 75		0.25
Delivering Pipe	245 68		0.015
Laying Pipe and setting Valves and Hydrants	1,556 00		0.095
Tamping, Backfilling and Trimming Trench	1,064 63		0.065
		17,607 41	$1.075
Building Intake and Developing Springs		1,081 65	
Building Reservoir		3,600 00	
Total cost		$61,000 00	

Average cost of labor 27½ cents per hour.

RAILROAD CONSTRUCTION

F. H CHESNUT, '08.

Gentlemen:—The subject which we are to consider is that of railroad construction. It is the object of this paper to bring before you in a concise manner what is required of an engineer on construction work.

If a line of railroad is to be constructed, say 100 to 300 miles long, the whole line is placed in charge of one man—the chief engineer. The line may then be divided into 15-mile to 50-mile divisions; each division being under the charge of a divisional engineer. These divisions are again subdivided into sections, which are under the supervision of resident engineers. Most companies also have bridge engineers each having charge of three or four bridges. It is, however, the duties of a resident engineer with which we are concerned.

We may conveniently divide his duties under two main heads:

(a) The laying out of the work and the office work resulting therefrom.

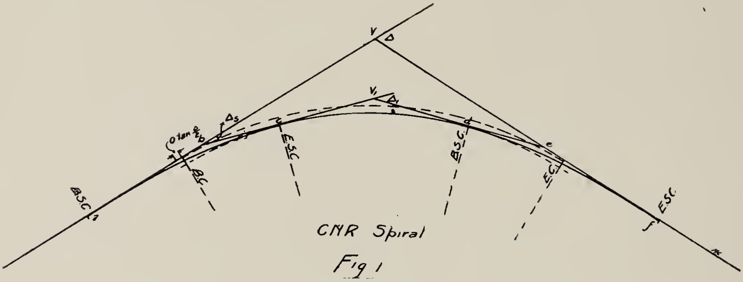
(b) The supervision of the work of construction.

Considering the first division:

When a resident engineer takes charge he is given a graded profile and plan (or notes of the same) of his section. The centre line is usually laid down on the ground, being marked out by stout stakes. As it sometimes happens the location has been made in the winter and for this and other reasons a number of the stakes may be pulled out or misplaced. Unless the engineer is absolutely sure that the centre line is correct, that is that all stakes are in place or that all tangents are straight or that all curves have been properly run, he should rerun the line, correcting all small errors in chainage and carry all equations in chainage through to the end of the section.

When the centre line has been properly fixed it is then required to spiral the curves which require easement. Some roads instruct their engineers to spiral all curves over 1° 30'; others require 3° curves and over to be spiraled.

Among the several forms of spiral is that used by C. N. R. resident engineers. It has proved very satisfactory and its simplicity makes it capable of being handled by even the novice. The following remarks on this spiral contain practically no theory, but simply the facts required to lay such a spiral down on the ground.



CNR Spiral

Fig 1

The C. N. R. spiral assumes (in most cases) chords of 30' in length, and one chord to be used per degree of central curve. That is to spiral a 4° curve we use 4 chords of 30' or 120' of spiral. To show the practical working of this curve we may examine the following example.

Suppose that we have a 5° curve with an intersection angle of 50°. We wish to spiral this curve using 30' chords.

Then 30' × 5 = 150' is length of the spiral.

At the *B S C* (Fig. 1) the curvature of the spiral is zero; at the end of the first chord it is 1°; at the end of the second chord it is 2°; and so forth until at the end of the 5th chord the curvature is 5° or the same as the simple curve. The curve has then an average of 2° 30'. Now a 2° 30' curve running 150' would consume 3° 45' in a central angle. Therefore 3° 45' is the central angle (*V b c*) of the spiral. The two spirals (one on each end of the curve) consume in all 1° 30' and this subtracted from the central angle of the main curve gives 42° 30' for the central angle (△) of the new 5° curve.

Then to find the *B S C.* The subtangent for the spiraled curve consists of three parts, viz., ½ the spiral = 75'; the subtangent for a 5° curve with an angle of 50° = 534.'3; and a variable quantity *O* tan ½ △, which varies with the central angle and the degree of the curve. A table of values of *O* tan ½ △

is given for curves up to 6° and angles up to 90°. By interpolation intermediate values may be found.

$$\text{Then } T_s = T + \tfrac{1}{2}\, S + O \tan \tfrac{1}{2} \triangle$$
$$= 534.'3 + 75.'0 + .381 = 609.6$$

Then we measured back from *V* 609.′6 or back from the *B C* 75.′3 and we are ready to run the spiral.

By reduction from theoretical formulae it is found that the deflection angles are as three times the square of the number

	VALUES OF O tan ½ Δ FOR 30′ CHORDS						
	Δ° = 30°	Δ = 40°	Δ = 50°	Δ = 60°	Δ = 70°	Δ = 80°	Δ = 90°
2° c	014	019	.024	.030	.037	.044	.052
3° c	.047	.064	.082	.102	.124	.148	.177
4° c	112	152	195	.242	.293	351	.419
5° c	219	.298	381	.472	573	.686	.818
6° c	379	515	659	.816	.990	186	1.414

AC

Fig 2

of chord lengths from the *B S C*. The right hand portion of the above table gives the deflection angles to be used for curves from 1° to 10°. For this curve we use for the 1st chord 3′; for the 2nd, 12′, and so forth and for the 5th, 1° 15′, turned off from the tangent *a b*. This last deflection fixes the *E S C* which then is 150′ from the *B S C* (measured along the curve). It is seen

Deflections For Last Spiral											
No. of Chord	Length of Spiral	Deflection angles for Curves From 2° To 10°									Def. ∠'s for 1st Spiral
		2°	3°	4°	5°	6°	7°	8°	9°	10°	
1	30	15′	24′	33′	42′	51′	1° 0′	1° 09′	1° 18′	1° 27′	3′
2	60	24′	42′	1° 0′	1° 18′	1° 36′	1° 54′	2° 12′	2° 30′	2° 48′	12′
3	90		54′	1° 21′	1° 48′	2° 15′	2° 42′	3° 09′	3° 39′	4° 03′	27′
4	120			1° 36′	2° 12′	2° 48′	3° 24′	4° 0′	4° 36′	5° 12′	48′
5	150				2° 30′	3° 15′	4° 0′	4° 45′	5° 30′	6° 15′	1° 15′
6	180					3° 36′	4° 30′	5° 24′	6° 18′	7° 12′	1° 48′
7	210						4° 54′	5° 57′	7° 0′	8° 03′	2° 27′
8	240							6° 24′	7° 36′	8° 48′	3° 12′
9	270								8° 06′	9° 27′	4° 03′
10	300									10° 0′	5° 0′

AC

Fig 3

from Fig. 1 that angle *v b c* = angle *b a c* + angle *b c a*. But angle *v b c* = 3° 45′ and angle *b a c* = 1° 15′. Therefore 3° 45′ — 1° 15′ = 2° 30′ which is twice angle *b a c*. Then setting up at *c* and sighting *a* we turn on to the tangent to the spiral (also the tangent to the central curve at this point) by turning through twice the angle we used to fix the point *c*. We are then prepared to run our central curve which is a 5° curve for 42° 30′ (or 805′ of curve); which brings us to *d*. If the circular curve were run past this point we would find that the spiral leaves this curve (on the outside) at the same rate as it left the tangent in the former case. Then to obtain the deflection angles from the *B S C* for the spiral we proceed thus: In 30 feet the circular curve would have turned from its tangent $\frac{30}{100}$ x 2° 30′ (def. angle for 5° curve) = 45′. But the spiral turns from the main curve towards the tangent in 30′ an angle of 3′. Then taking the difference we find that the spiral leaves the tangent *d e* 42′ for the first chord. In the same way for the second chord the curve turns in 60′ through $\frac{60}{100}$ x 2° 30′ = 1° 30′; but the spiral leaves the curve 12′ for 60 ft. ∴ the spiral leaves the tangent 1° 18′ for the second chord. The left hand portion of the above table gives the deflection angles for curves from 2° to 10°. Turning off 2° 30′ we set a hub 150′ away (measured on the curve) and this is the end of the spiral and should come on the main tangent if the curve has been carefully calculated and run properly. If trouble is found in fitting the curve in, it may be run from both ends and flattened slightly in the middle; but such a course should not be followed except as a last resort. This form of spiral may also be applied to existing track; but in this case while the middle point of the central curve remains unchanged the curve is sharpened.

When all curves which require it have been spiraled we then have the centre line fixed absolutely. It now remains to permanently fix it, that is, to reference a number of the main hubs out to the sides of the line. Many good methods will suggest themselves to the engineer. It may be well, however, to note that heavy hubs (6 in. in diam. where possible) and large guard stakes (3 ft. long) should be used to insure against uprooting by frost, etc.

We have now the centre line permanently and accurately fixed, and are in a position to commence cross-section work. This should be commenced at one end of the section, when possible, and carried right through to the other, thereby keeping the notes in good shape. Before cross-sectioning is actually started, check levels should be run over all bench marks, small errors corrected and bench marks placed at convenient points, such as large cuts or where trestling is proposed. Cross-sectioning is then carried on by the ordinary method which is so well known as to require no explanation. It may be said, however, that slope stakes should be placed at every station of 100′ and grade plugs where the centre line and the two edges of the roadbed come to grade. Sections should be taken at these grade points if accurate volumes are expected. This should be carefully noted as it is a frequent source of error. In cross-sectioning due allowance should be made for vertical curves at the meeting of two steep grades. Simple methods of running these curves will be found in most engineers' hand-books.

If bridging or trestling is proposed it is the duty of the resident to take careful cross-sections of ravines or river crossings, plotting his results on cross-section paper using scales of 10′ = 1″ horiz. and vert. Soundings should also be taken in swamps or muskegs which have the appearance of being too soft to hold a dump. These soundings can be conveniently taken by joining several lengths of gas pipe together, the end one being hammered to a point. You will base your judgment as to whether a dump or trestle will be required, on the resistance the ground offers to the rod and the distance to which you can sink it. It must be remembered, however, that trestles are only temporary and will be replaced by embankments when they begin to show signs of failure. For this reason embankments are preferable even if cross-logging has to be resorted to in order to keep the dump from sinking.

Proceeding to the office work, we will find that the first thing which presents itself is the working out of the cross-section notes or in other words the finding of the volume of material in cuts and fills between their respective grade points. This is usually done by the well-known method of end areas and is accurate enough for almost the most exacting. An office cross-section book should be kept with its pages ruled as follows:

Sta.	Area	M. Area	Dist.	Cu. Ft.	Cu. Yds.

Fig. 4

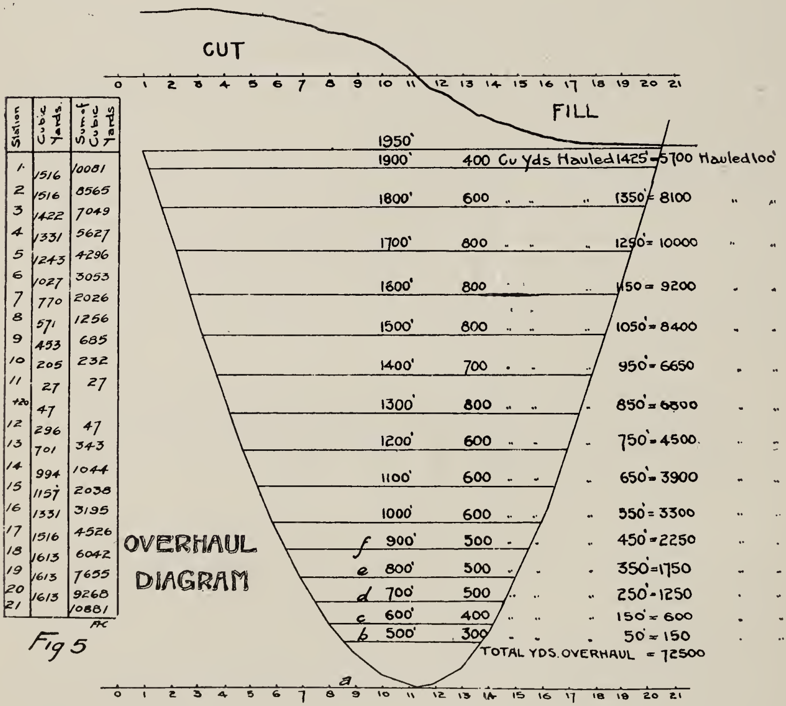
It is not necessary to fill out the column for cubic yards between each cross-section station except in cuts and fills where overhaul is to be calculated.

In the office also should be kept a book of general information. Starting at one end of the section, this book should contain all information with regard to yardage in cuts and fills, lengths of pipe in drains, culverts and farm crossings, yardage in farm crossings and public road crossings, yardage in borrow pits and side ditches, farm gates and all other information available. Everything set down should be in order of stations and put in such a lucid manner that any one glancing over the book could formulate an idea of the work being carried on.

Most companies require the engineer to keep what is known as the Force Account or the number of men and teams which the contractor has working each day. This should be returned to the divisional engineer every week or so. The object of this

Force Account is to obtain data from which can be calculated the exact cost of building a line. Knowing the force the contractor has on and the cost of labor, teams and material, we can arrive at a very close estimate of actual cost. From these figures it is possible for a railway company to judge closely what other work will cost, taking into account differences of prevailing conditions.

When material is hauled over a certain distance (freehaul usually 500′) it is known as overhauled material and is paid for at so much a cubic yard for each hundred feet hauled over the freehaul distance (usually one cent). The best method in use for finding this yards overhaul is the graphical method here illustrated.



Station	Cubic Yards.	Sum of Cubic Yards
1.	1516	10081
2	1516	8565
3	1422	7049
4	1331	5627
5	1243	4296
6	1027	3053
7	770	2026
8	571	1256
9	453	685
10	205	232
11	27	27
+20	47	
12	296	47
13	701	343
14	994	1044
15	1157	2038
16	1331	3195
17	1516	4526
18	1613	6042
19	1613	7655
20	1613	9268
21		10881

Fig 5

From the book containing the volumes calculated from the cross-section notes, we may formulate a table as shown. The second column contains cubic yards between cross-section stations and the third column these cubic yards summed to each cross-section station on each side of the grade point. Then on the same paper on which our profile of the centre line is plotted we may plot the overhaul curve, using any convenient vertical scale of cubic yards per inch and the usual horizontal scale of 400′ = 1″. Thus the ordinate to the curve at station 7 represents to scale the quantity of material between station 7 and the grade point, as also the ordinate to the curve at station 15 represents the quantity of material between station 15 and the grade point. When the curve has been plotted back as far as the cut has been excavated (say station 1), and in the fill far enough to balance this, we take a 40 scale and sliding it up the curve, keeping it horizontal, we find the height at which 500 scaled feet will just fit between the curves; drawing a horizontal line we proceed until 600 scaled feet just fit between the curves. Thus to the top of the curve. We have now found different points in the cut where material is hauled distances differing by 100 feet. It is readily seen that the amount of material removed before we begin to haul 500 feet is represented by the vertical ordinate to the first horizontal line and is called the freehaul. This can be found by scaling. In the same way b c represents the number of cubic yards of material removed between the hauls of 500 and 600 feet, and c d, d e and e f each represent the cubic yards of material removed between their respective limits. It is seen that the 300 cubic yards of material between b and c have been overhauled from zero to 100 feet, or an average of 50 feet. 300 cubic yards hauled 50 feet = 150 cubic yards hauled 100 feet. In the same way we have 400 cubic yards hauled 150 feet = 600 cubic yards hauled 100 feet. Adding up the cubic yards overhaul we have the total yards overhaul for the cut.

In connection with office work the question of estimates may be considered. At the end of each month the engineer is expected to furnish an estimate of the amount of work done during the month. Most companies have a prescribed estimate form which should be filled out neatly, keeping everything in order of chainage. Quantities may be somewhat approximate for monthly estimates; but the approximations should not exceed the possible. Along with the estimate sheets a progress profile should be sent, showing the excavations moved and the embankment constructed during the month. This profile should be an intelligent history of the progress of the work, showing length and kind of structures; date work was begun and finished; road and farm crossings graded; notes as to the character of the soil and any other data tending to give a complete knowledge of the work in progress. Final estimates should be made upon the same manner, but should contain only exact double-checked quantities.

We have now completed what might be called the theory of this branch of engineering, and pass on to the supervision of the work of construction.

Apart from the actual grading, the most important consideration is that of drainage. The engineer should see that not only is the railroad right-of-way properly drained but that the land owners on both sides get a fair deal. It often happens that the work of construction destroys what is known as natural drainage, thus throwing the water off one person's land onto another property. Each case which comes up requires a different remedy and all that can be said is that judgment and patience are the chief factors in obtaining a well-drained line from the company's as well as from the land-owners' standpoint.

When water is to be drained across the line we use a culvert of some form, of which we will mention several styles. Pipe culverts are largely used and are made in sizes from 6″ to 36″ diam. They are of two main styles, concrete (smooth joint) and burnt tile (bell point). The former is preferable on account of having a smoother outer surface when laid, thus lying flatter and keeping its alignment better. Tile pipe costs when laid about $1.25 per foot (24″) and concrete somewhat more. When double pipe are used they should be laid in separate trenches with a 6″ dividing wall. Cedar box culverts consisting of 10″x12″ cedar timbers (dressed on three sides) laid one on the other and spiked together form a cheap and easily made culvert. Such culverts, while not having such a long life as pipe, last for over fifteen years, in some cases without repair. Built cedar culverts of this type cost from $42 to $45 per 1,000 feet of timber including spikes. Many companies in reconstructing their lines have made use of concrete arch culverts. These will cost about $12 per cubic yard of concrete and give a practically everlasting article. A four bent trestle is frequently used where streams of twenty feet cross the line. These may be either pile or frame bent and where piles cannot be driven mudsills may be used to support the bents.

All culverts should be laid out with a level and have a slope of at least 5-10′ in their length.

Fencing should be started as soon as possible after grading commences, or better even before, thus saving much damage to crops in the vicinity, due to carelessness on the part of the contractor's men. The woven wire fence is largely used at present and gives entire satisfaction if properly erected; that is, it should be strung tightly and remain so. Posts should be sunk 3½ feet in the ground and well tamped with earth. To keep the fence from sagging the ends of each separate stretch of fence should be braced and where the stretch is long intermediate braces should be put in.

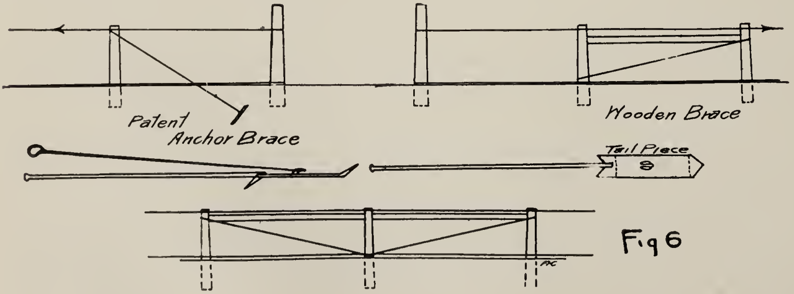


Fig 6

Fig. 6 shows a patent anchor brace in use. The tail-piece is driven into the ground with an iron rod. When the rod is removed and a strain placed on the twisted wire the tail-piece turns to a position at right angles to the wire, thus preventing its being pulled out of the ground. It will be noted that instead of bracing the gate posts as is often done we brace the next post away on each side, thus leaving the gate post free to hold up the gate alone. Wooden bracing is also shown in coincidence with wire and will be found to act most efficiently if placed horizontally instead of laterly.

Where the right of way cuts a farm into two parts, the owner generally has an agreement by which he gets a farm crossing over the grade. These must be graded with the rest of the work and have an extra 1′.5 to allow for ballast, etc., on the line.

It sometimes happens that enough material cannot be obtained from line cuttings to make a certain fill and so a borrow pit has to be opened. In side borrows a berm of 4 feet at the toe of the slope and 3 feet at the fence should be left. The engineer should be sure that a borrow is not made unless necessary, for if after the fills have been made and a balance is left in the cuts this will have to be washed. It sometimes happens that waste is unavoidable and in this case the material should be used to widen the dump below grade.

In some cases the embankment may run alongside a river or lake where, if it is of earth, may be damaged or washed out. This danger is overcome in some cases by rip-rap, which may be of two kinds—loose and hand-laid. The former is made by simply rolling large stones over the bank and allowing them to pile up at the bottom of the slope. The latter consists of flat stones laid one on the other, thus forming a wall four or five feet in thickness and running the length of the endangered line. Timber cribs are sometimes built and when filled with stone prove very effectual as a protecting wall.

All bush and timber must be removed from the right of way and stumps (in fills between 4′ and 1′.5 in height) must be sawed down close to the ground. Those in cuts under 3′ and fills under 1′.5 must be grubbed out by the roots and will be paid for by the acre.

Where a cut contains a number of different kinds of material it must be classified, that is the percentage of each class of material judged. Different specifications call for different requirements defining each class, so all that can be said is that the specifications should be interpreted upon the broad grounds of common sense and professional intelligence.

When grading is finished the engineer should run track centres, picking up the line from his reference hubs. Small equations in chainage no doubt will be found and should be run through to the end of the section. A final transit book should be filled out showing correct chainage of all hubs and their permanent reference marks.

Having dealt, in some detail, with the duties of a resident engineer on construction, it remains but to add that the engineer is employed by the railroad company to protect its rights and to enforce the ruling of the contract in such a way that the contractor gets a fair deal. The engineer is to be the sole judge of the interpretation of the claims of the contract, and it is his business to see that quick, thorough, business-like judgment is given in all cases. He must treat the contractor in a business-like manner if he expects business to be done. The contractor is there to make all he can out of the job and the engineer must endeavor to help him in this with the contract as the bounding limits.

A NEW APPARATUS FOR MAKING CARBONIC ACID GAS

*J. A. DECEW '96,

An improved apparatus has been devised with the object of utilizing to the greatest possible advantage, the well-known property of an alkaline liquid, such as potassium carbonate, of readily absorbing especially under pressure, carbonic acid gas and so forming a bi-carbonate. This bi-carbonated solution when boiled gives up the carbonic acid with which it has been saturated, and is, during and after cooling, again ready to absorb CO_2.

The raw material employed is carbon, in the form of coke or charcoal, and the furnace gases, resulting form its combustion, containing about 20 per cent. of carbonic acid gas, are used for bi-carbonating the liquors.

The cleansed furnace gases are forced successively through bi-carbonaters in such a manner that during their passage through the lye in the bi-carbonaters, practically all of the CO_2 they contain is absorbed by the lye, and what escapes is merely residual inert gases with a little steam. The process is termed bi-carbonating.

Simultaneously, with the process of bicarbonating, there is another and opposite process of de-carbonating going on in another portion of the apparatus. Here the bi-carbonated lye is heated in a suitable boiling-off vessel by steam or otherwise, to a temperature of 212 degrees F. and higher in order to decompose the bi-carbonate which it contains. The CO_2 thus released passes through a suitable gas cooler to a gas holder, whence it is drawn for use. The supply of gas to the gas holder is easily

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* Chemical Engineer, Montreal.

regulated by increasing or decreasing the lye or heat supply to the boiling-off vessel.

It will be noticed that these two processes, although they go on at the same time, are not only independent of each other, but also opposite in result. Upon their completion the lye in the bi-carbonator has become saturated with CO_2, while the lye in the boiling-off vessel has been freed from CO_2.

These operations constitutes a complete cycle. They are controlled by means of suitable valves, the operation of which is effected by rotating a hand wheel, so that all that the attendant has to do, when the time comes to change from one of these operations to the next, is to turn the hand-wheel. With this simple method of control, there is no possibility of an accident, nor of the CO_2 produced being anything but pure and free from air.

The yield of carbonic acid gas is extremely satisfactory, for of the 20 per cent. contained in the furnace gases from coke suitably burnt, the apparatus extracts practically all. In quality and odor the CO_2 produced is excellent, being better than that obtained from whiting, agreeable to the palate and free from twang.

An important feature of this new process is its use of pressure to accelerate absorption, and so to reduce the space occupied by the plant. Unlike any other process for producing CO_2 from coke, it puts the furnace gases under pressure before passing them through the lye, thereby rendering it possible to use a lye of much more than usual strength, with a corresponding increase of speed in carbonating, and decrease in the size of the vessels.

Pressure is also utilized in this plant, to minimize the number of moving parts. Instead of employing a pump to circulate the lye, as is usually done, the inventor has taken advantage of the fact that the temperature required to decarbonate the lye can also be used to produce in a confined space, Pressure sufficient to force that lye from the lowest to the highest vessel of the apparatus, the remainder of the lye circulation being effected by gravity.

As contrasted with the method of producing CO_2 from chemicals, this process offers distinct advantages. It requires no sulphuric acid, which is always a dangerous article to handle, and liable, as is well-known, to contain arsenical impurities. Nor is there any chance of contamination as with whiting, since the lye employed is not at any time exposed to contact with anything except washed and cleansed furnace gases. Nor are there any objectionable bye-products, such as sulphate of lime, to dispose of.

Once the appartus has been adjusted and started, it requires merely its daily supply of good coke, than which nothing is less subject to impurities, and water for washing and cooling the furnace gases and for cooling the CO_2.

In economy, in cost of raw material, this new patent apparatus is signally successful. The manufacture of one ton of CO_2 from acid and whiting involves a consumption of raw material, which costs in England, where the process is in operation, about $70.00, (seventy dollars), whilst the above plant consumes only eight hundredweight of coke, costing about $2.50, in producing the same quantity of gas. The factory, labor and adminstrative charges being about the same in each case, there is an average gross saving of $67.50 per ton of CO_2 produced. Allowing, however, for the maintainance of the plant, and for conditions where the operator does not work his plant to its full capacity, he yet makes on an average a saving of $25.00 to $40.00 per ton, according to the size of his plant. By replacing old plants with this system an annual saving is made which will amount to 70 to 100 per cent. upon the investment.

The apparatus can be built in sizes having a daily capacity of from one hundredweight to five tons, and would be serviceable to all makers or users of pure carbonic acid gas.

MEASUREMENT OF INDIVIDUAL RESISTANCES IN A NETWORK

T. R. ROSEBRUGH

The problem sometimes arises of finding the resistance of one or all the conductors connected to each other at certain points.

These points may be termed branch points, and if sufficiently numerous, the whole group of conductors so connected may be appropriately termed a network.

In some cases the arrangement is accessible throughout and any desired conductor may be isolated for measurement, so that no new problem is presented. In others, as for instance, insulation resistances, it may not be possible to do anything of the kind. This leads to our problem.

For example, suppose in a building there are three mains with branches nominally insulated from each other and from ground ; we may consider it possible that some conductance is present between each of the wires and ground (three paths), and between the three wires (three paths).

These may be indicated diagrammatically as in Fig. 1, *A*, *B*, *C* and *D* representing respectively the three wires and earth.

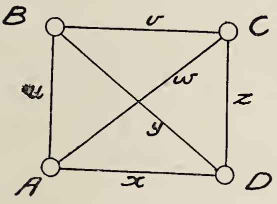


Fig. 1

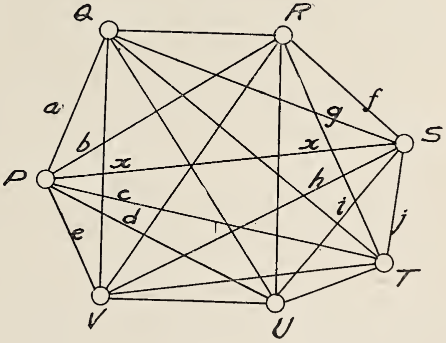


Fig. 2

A principle may be employed for determining these resistances (or more conveniently their reciprocals, the conductances) which can perhaps be better understood in the case of more numerous branch points.

If seven branch points be selected as an illustration, the diagram will be as shown in Fig. 2.

Suppose now that these branch points are all accessible and that we can join any of them we please together by a wire whose resistance may be neglected in comparison with the resistance to be determined, we may then proceed as follows :—

(a) Short-circuit together all but P, and measure the conductance between this group and P. Call this p.

(b) Short-circuit together all but Q, and measure the conductance between this group and Q. Call it q.

(c) Short-circuit together all but P and Q, and measure the conductance between this group on one side and P and Q united on the other. Call this $\widehat{pq}$.

Let the unknown conductances have the values marked in Fig. 2.

Then
$$\begin{aligned} a + b + x + c + d + e &= p \\ f + g + x + h + i + j &= q \\ a + b + c + d + e + f + g + h + i + j &= \widehat{pq} \end{aligned}$$

Therefore
$$x = \tfrac{1}{2}(p + q - \widehat{pq})$$

Applying the same notation for the conductances measured between points and groups, and lines and groups to Fig. 1, the following results may be written down from inspection.

$$\begin{aligned} x &= \tfrac{1}{2}\,(a + d - \widehat{ad}) = \tfrac{1}{2}\,(a + d - \widehat{bc}) \\ y &= \tfrac{1}{2}\,(b + d - \widehat{bd}) = \tfrac{1}{2}\,(b + d - \widehat{ac}) \\ z &= \tfrac{1}{2}\,(c + d - \widehat{cd}) = \tfrac{1}{2}\,(c + d - \widehat{ab}) \\ u &= \tfrac{1}{2}\,(a + b - \widehat{ab}) = \tfrac{1}{2}\,(a + b - \widehat{cd}) \\ v &= \tfrac{1}{2}\,(b + c - \widehat{bc}) = \tfrac{1}{2}\,(b + c - \widehat{ad}) \\ w &= \tfrac{1}{2}\,(a + c - \widehat{ac}) = \tfrac{1}{2}\,(a + c - \widehat{bd}) \end{aligned}$$

It will be noted that $\widehat{ad} = \widehat{bc}$ (and similar equalities) because they are two different designations for the conductance measured in the same experiment, namely from A and D joined to B and C joined.

From the above it appears that seven measurements of conductance, namely
$$\left.\begin{array}{l} a,\ b,\ c,\ d, \\ \widehat{ab}\ \ \widehat{ac}\ \ \widehat{ad} \end{array}\right\}$$
are sufficient to determine by symmetrical formulae the six unknown conductances x, y, z, u, v, w, and the corresponding resistances may then be found by taking reciprocals

A little further examination will also show that seven measurements also furnish the check
$$a + b + c + d = \widehat{ab} + \widehat{ac} + \widehat{ad}$$

In the practical application of this method apart from the precautions necessary to secure good measurements of somewhat variable electrolytic conductance (when measuring insulation) it should be kept in mind that relatively small conductances will be given as the difference between quantities each of which is the sum of several larger quantities, hence accuracy should in such cases not be expected.

GOLD DREDGING

W. F. WRIGHT, B.A.Sc.

The gold dredging industry, which is, in itself, one of the most prosaic imaginable, has been a gradual evolution with its beginning in the romantic placer mining, where two miners used pick and shovel and hand screen, and barely made an impression on the same large fields which are now being worked by the aid of large power dredges. Probably the main reason for the present-day lack of interest is due to the fact that dredging is never begun until a preliminary examination has shown the actual values, and then the profits are a sure thing and only of interest to those financially interested in the proposition.

Gold dredging was first begun in New Zealand, where the pioneer miners dredged the sandy bottoms of the Molyneux River with leather bags riveted to iron hoops on the ends of long poles.

About the year 1867 steam power was used to operate a chain of these buckets, and as their capacity was increased they were made out of iron. About five years after this the dipper dredge was introduced, and has been itself gradually displaced by the continuous bucket dredge. The reasons for this will be given later.

At present there are over 300 dredges in operation in New Zealand; about 60 or 70 in California, and others scattered throughout the West in Montana, Colorado, Idaho, New Mexico, Oregon, British Columbia, Mexico and South America.

There are three types of modern dredges:

1. Section pump.
2. Dipper or single bucket.
3. Continuous bucket.

The suction pump is very satisfactory for shallow fields with sandy soil, but is very liable to lose a great deal of the gold, as it cannot remove boulders which lie along bed rock where the deposits of gold are heaviest.

The dipper dredge was for many years the favorite, as it had been very highly developed for marine work and could be relied on for continuous service, but it was far from an ideal machine. Some of its disadvantages were:

(1) Its small output considering maximum power required.

(2) The agitation of the water due to the irregular operation caused great losses of gold values.

(3) Irregular operation of the gold saving devices due to the intermittent dumping of the buckets.

(4) Great trouble of washing and disintegrating the great masses of material when clay is present.

Dipper dredges have been built with a capacity of 30 to 33 cubic feet per dip, but owing to the long intervals between operations the monthly capacity is small, and the bed rock is not thoroughly cleaned, as the operator can hardly guide the dipper to the exact spot where the last shovel full is taken out.

The continuous type of dredge appears to be as near perfection as can be obtained, but is itself constantly undergoing improvement, so that one would hesitate to predict the details of the dredge which will be used in another ten or fifteen years.

The buckets are from 3 to 14 cubic feet capacity, and their arrangement extends to a certain extent on the nature of the field. A gravel or sand bed is best worked with a close bucket dredge, while clay and rocky fields are more easily handled with dredges of the bucket and link type. Dredges of even moderate capacity will handle boulders weighing nearly a ton without great difficulty, and will dig a distance of 30 to 45 feet from the water level to bed rock, and by elevating the tailing conveyor another 30 feet can be obtained, so that a total depth of 70 feet can be handled. The speed of the bucket line is 45 feet per minute average. A 5 ft. dredge will handle 75,000 cubic yards per month. The digging apparatus has been so highly developed that the capacity is practically limited by the washing apparatus.

The washing apparatus consists of a shaking or revolving screen, riffles and quick-silver on the sluices or cocoa matting with expanded metal mesh on the sluices, and either a belt or continuous bucket conveyor for disposing of the tailings. Water is furnished by centrifugal pumps for washing the boulders and disintegrating the clay.

All the early dredges were steam operated, but the modern tendency is towards electric power, which can generally be cheaply obtained from water powers within a reasonable distance of the fields.

Electricity gives a much cleaner and more pleasant power than steam, and is in a great many cases less costly, and its great reliability obviates many delays which, in this industry, are the greatest loss.

The power required for a dredge varies, of course, with the different conditions, but a small dredge, i.e., 5 cu. ft. dredge, requires about 130 h.p., while the larger sizes require about 400 h.p., divided as follows:

Main bucket drive	200 h.p.
Centrifugal pump for washing	75 h.p.
Winch motor	35 h.p.
Sand pump	75 h.p.
Stacker motor	25 h.p.
Auxiliary pump	15 h.p.
	425 h.p.

These amounts vary also with the various makes, but represent a fair average.

One ordinary dredge requires a crew of about eight men and operates on an average from 16 to 18 hours per day, and cost approximately six cents per cubic yard for excavating, and the loss in gold in the tailing is not over about ten cents per cubic yard, so that any property showing over forty cents on prospecting can be worked at a good profit. A great many fields show values averaging at least one dollar per cubic yard.

Prospecting is generally done with a drilling machine, which sinks a hole about seven inches in diameter. A hole to every ten acres is considered close prospecting, and by actual experience it has been found that about 70 per cent. of the values obtained in prospecting can be realized.

When the ground is frozen it is necessary to use steam to thaw the ground. "Steam-points" are driven into the ground about eight or nine feet apart, and the same distance from the face of the bank and moved along as the work progresses.

NEW PHOTOGRAPHIC PROCESSES

G. R. ANDERSON.

Great interest has been awakened in photographic circles within the last few months by the announcement that the firm of Lumiere & Sons had perfected a new screen plate for the production of transparencies in color. These plates have lately been tried in the photographic laboratory and the results already obtained confirm the claims put forth by the manufacturers. The color screen consists of a layer of starch grains, stained red, green and blue-violet sifted over a plate previously coated with a retaining substratum, and over this layer of colored starch is then spread a panchromatic silver emulsion. The plate is exposed reversed in the camera so that the light passes through the screen to reach the sensitive coating. To reduce the action of the blue and violet light a medium yellow screen is used similar to that employed with the common orthochromatic plates.

Development is carried out as usual, after which the negative is converted to a positive by the action of potassium permanganate. It is then re-developed, intensified in a silver bath and fixed. The operations although numerous are quickly performed and a slide may readily be shown on the screen within an hour after commencing operations.

As might be expected, the plate is comparatively slow owing to the combined action of the yellow screen on the lens and the color screen contained in the plate itself, the exposure required being apparently about forty times that necessary for a rapid plate such as Seed's or Cramer's. If the exposure is correct the colors are reproduced with remarkable fidelity; under-exposure gives a somewhat bluish tinge to the image while overexposure results in a pink.

Since every portion of the plate is overlaid with a layer of starch grains, it is evident that an "autochrome" slide will appear denser than an ordinary one of the same subject, for in the latter case the whites of the picture are but clear glass whereas in the color slides the white portions result from an equal mixture of red, green and blue light passing through the corresponding colored grains which are only partially transparent. If the projected image is 35 or 40 times the size of the slide the grain of the plate becomes apparent at close range and detracts somewhat from the effect; for this reason and also on account of the greater density better results are secured by arranging the lantern for a smaller image than is ordinarily used, say five or six feet.

Compared to the older tri-color process with three separate negatives and three corresponding positives or the modified triple line screen plate process of Joly, the Lumiere method is vastly superior in ease of manipulation, certainty of results and superiority of rendering, and must necessarily prove of the utmost value in scientific work where color rendering is important.

Carbon workers will be interested to learn of the invention of a new tissue of much greater sensitiveness than any already in use. This paper, known as Carbograph, is manufactured by the Rotary Photograph Company, of London. The coating consists of the ordinary pigmented gelatine incorporated with a bromide of silver emulsion, by which a speed of from three to five times that of rapid gas light paper is attained. This speed renders the paper available for direct enlargements either by daylight or the electric arc, and as the negative may be reversed in the enlarging camera the very troublesome operation of double transfer is avoided.

The manipulation is as follows: After exposure the paper is developed, preferably in a ferrous oxalate developer and after a short immersion in an acid bath is sensitized in the usual bichromate of potassium solution. It is then given a short washing and squeezed to its support, and after a short interval the final development takes place in warm water as in the ordinary carbon process. When the latter development is completed the paper must be immersed in a hypo bath to remove the unaltered silver bromide. It is evident that the image will consist of reduced silver from the silver bromide emulsion and the pigment incorporated with the gelatine.

The paper possesses two notable advantages, viz., its very much greater rapidity and easier manipulation and the greater strength and brilliancy of the image. For the ordinary carbon process negatives of great contrast are required since the print is always very much softer than the negative, but with the Carbograph paper such tests as have already been made in the laboratory show that vigorous prints may be obtained from relatively thin negatives. Should the print appear to possess too great contrast the silver may be reduced or entirely eliminated by a ferricyanide reducer or if it is too weak an intensifier may be used as in a bromide print or negative. To those who wish to make carbon enlargements the paper will prove especially serviceable and of course it may also be used for contact printing although in this case either a reversed negative or double transfer is necessary.

PLANE TABLE TOPOGRAPHY

W. TREADGOLD, 04

In most all topographic surveys covering an extended stretch of country, in order that the topographer may have points definitely fixed in position and in elevation which will control and guide him in his subsequent work, a system of triangulation is carried out. The work of primary triangulation and its expansion from a base, consists in the selection of stations, in the erection of signals and in the measurement of angles. Stations are so selected as to give a commanding view of all the surrounding country, to give well shaped triangles and so as to group these into simple quadrilateral, pentagonal or similar figures. They are also so selected as to serve best the needs of the topographer. This requires that they shall offer suitable bases from which to expand the secondary triangulation and that at least two, preferably three, points shall fall within each sheet used in plotting.

The primary triangulation being completed, a preliminary computation of the positions and distances between stations is made in the field and these data are furnished the topographer as a basis on which to construct his graphic or plane table triangulation. From this point forward, all the work is represented on the plane table sheets, thus requiring the keeping of no cumbersome notes which must be worked up at some future time in the office, while the progress of work from day to day is always observable.

Having, then, located a sufficient number of points, properly distributed over the area to be surveyed, which form a strong framework for controlling the accurate location of the various details, the topographer is then in a position to proceed with the secondary triangulation which is made by means of the plane table.

The plane table is composed of a well-seasoned drawing-board about 30 inches in length, 24 inches in width, three-quarters of an inch thick, with bevelled or rounded edges. It is commonly made of several pieces of white pine, tongued and grooved together, with the grain running in different directions to prevent warping. It is supported upon three strong brass arms to which it is attached by screws passing through them and entering the underside of the board. It is connected with the tripod by means of a ball socket joint. When loose this permits of the board being revolved in a horizontal plane about its centre and when clamped holds the table firm. The board can be levelled by means of levelling screws, two cross levels being placed on the board and shifted until at any position it appears level. The tripod and board should be designed so as to be neither heavy nor cumbersome (a common fault with many patterns) yet combining the elements of stability, lightness and firmness.

The type of alidade in general use consists of a brass or steel rule, nickel plated underneath, from and perpendicular to which rises a brass column (3 inches high), surmounted by Y's, receiving the transverse axis of the telescope, to one end of which axis is firmly attached a graduated arc of 30°, each side of a central 0°, an accompanying vernier being attached to the lower end of the Y support. The arc moves with the telescope as it is raised or depressed and it is used in the measurement of the vertical angles from which height is determined.

A clamp and a tangent screw placed on the other side of the telescope, opposite the arc, controls its vertical movement. The eye piece carries the usual diaphragm, with screws for collimation adjustment, which has one vertical and three horizontal wires. The horizontal wires are used in order that stadia readings might be taken and so points of detail at once located. The telescope is mounted firmly on to the ruler as by the method of location of points employed no readings of horizontal angles are necessary.

Each plane table sheet is complete within itself, and on it little is recorded other than the graphic triangulation and a little sketching of the immediate summit of the hill occupied. From the standpoint of efficiency the plane table sheet is the least satisfactory portion of the equipment. It is very susceptible to atmospheric changes, expanding and contracting unceasingly. This might be overlooked if this were the same in all directions. But the objectionable feature arises from the unequal expansion and contraction which changes the relative distance and direction of the points. Various substitutes have been tried but none have proved entirely successful.

To reduce the distortion the sheets of paper used should be thoroughly seasoned before taken to the field and this is effected by exposing it alternately to a very damp and very drv atmosphere. Two sheets of paragon paper are often employed the size of the plane table board, mounted with the grain at right angles and with cloth between them.

Besides the chief topographer in the party there is always an assistant whose usefulness to his chief is limited only by his skill and experience. The logical inference being that he is in training to become a topographer himself, he takes charge of an increasing share of the work as he becomes more and more familiar with the methods employed. This enables the chief to turn his attention in other directions, which will expedite the survey and increase the amount of work done. Two rodmen are needed and the rapidity with which the work is carried out depends upon their efficiency. When well trained they should be able to recognize the salient points of the features of the ground to be mapped, so that the topographer can draw in correctly the details from the least possible number of readings.

The work involved in the carrying out of a survey might reasonably be classified under three heads:

1. Plane table work proper, involving exact location of points, in plan and elevation, of the secondary triangulation.

2. Detail work, including traversing of roads by means of a light plane table and cross country traverses by means of the stadia.

3. Sketching of the map.

1. Plane Table Work.—On taking the field the topographer has, in addition to the triangulation points accurately plotted upon his plane table sheet, all such data as he has been able to gather from railway surveys, city engineers' offices, county surveyors or from state or national organizations, so that he is able to make best use of such material as has been obtained from prior surveys, examining and checking this in the field in order to assure himself whether it is sufficiently correct for adoption. A reconnaissance of the country should then be made for the purpose of recovering triangulation stations and to locate signals at suitable points for subsequent determination and use. The object of this work is to locate a sufficient number of points to enable the traverse man accurately to tie in his traverse surveys which are made for the purpose of gathering together detail. The chief method used in determining these points is that of intersections. It requires some little experience to decide which are the points worthy of location and having decided to fix them in the mind so that they may be recognized and located from another station. Besides they must be described sufficiently that the traverse man may identify them with locations of his own. After signals, which are of a temporary character consisting usually of a properly braced rail or pole from 10 to 15 feet high on which a cloth flag about one yard square is fastened, have been erected, the topographer then proceeds to occupy each of his stations in succession, obtaining intersections upon other chosen stations and upon all such objects as hilltops, lone trees, church steeples, houses, etc., as will probably be seen and identified from other stations. He also reads and records vertical

angles to all these objects, so that when his secondary triangulation is completed his plane table sheet has located upon it a great many natural and artificial objects, the vertical elevations and horizontal positions of which are recorded.

2. Detail Work.—On an extended survey while the secondary triangulation is being made the assistants are carefully traversing all roads, etc. For this purpose they often use a lighter form of plane table, having no levelling apparatus, on which is a compass needle, the alidade employed being an open sight ruler about 10 inches long. With these instruments and with the aid of distances measured by an odometer on the wheel of the buggy or cart in which he rides, the assistant traverses every road in the area to be surveyed. He sights to natural objects in the road, usually a sharp bend, orienting his board by means of the compass needle. He sets up his instrument at every other station, taking fore and back sights, and plots frequent lines to the prominent objects about him, as hilltops or other salient features, which he thinks the topographer may locate. In this way he obtains a means of connecting his work with that of the topographer, more especially as he locates all houses on the line of his traverse and the topographer intersects on many of these.

In the writer's opinion it would be just as cheap and easy to make the traverses throughout by the stadia method. All detail could be obtained in that way. The instrument man could set up at a known point of the secondary triangulation, carry a traverse line across country, in the meantime locating prominent and characteristic points by a single reading, finally checking up on the first convenient point of triangulation that comes within reach. It has been demonstrated time and again that the method is economical and gives, with sufficient care, any degree of accuracy that is required. With the small plane table it is necessary to keep to the open roads and these as a rule are not found in the greater part of the country of which a topographical map has to be made. Where bodies of water and rivers are to be surveyed this is the only practical method that can be used. If the country is of such a character as to be lacking in prominent and characteristic features and of a regular easy sloping surface the use of stadia readings is to be highly recommended.

3. Sketching of the Map.—Now the topographer has on his map the positions and elevations of all points of both his secondary triangulation and stations along the different traverses. These give him rigid control over all sketching work which remains to be done. He starts at any point of a road or traverse and makes a small circuit, sketching as he goes the real shape of the ground, checking his levels by means of an aneroid, assuming of course that the elevation of his starting point is known. He sketches these contours in as far as he can follow them, on each side of the road, using the points located by the road traverses and

plane table to check his bearings, distances and elevations. This work is greatly assisted by numerous locations off the road in the proper places and the traverse man would do better to have too many auxiliary points than too few. It is by far the most difficult part and to sketch well a great deal of experience is necessary. The object of the work is seen at a glance. Practice and in most cases a great deal of practice, is the only means which will enable one to arrive at the desired result.

The United States Coast and Geodetic Survey have used this method almost entirely in the carrying out of this great work throughout the United States and the results have been very successful in every part except the very rough, inaccessible, mountainous country. In the marking of the boundary between the United States and Canada on the 49th parallel in British Columbia, it was decided by a joint boundary commission that the work should be done by each government in alternate sections, each section to overlap by almost a mile or so. The method used for the work by the United States was of course the plane table and that used by the Canadian Government parties, that of photographic surveying, so that when the maps are complete it will be interesting to compare the amount of accuracy and detail obtained by one method when compared with the other.

THE COMMERCIAL SIDE OF ENGINEERING

K. L. AITKEN, Consulting Engineer.

My remarks this afternoon will be almost entirely from an electrical standpoint, and it is my intention merely to touch on the principal features of what I call the "commercial side" of engineering.

At present, the word "engineer" may be defined as "a person versed in the commercial and practical application of the sciences." ·Electrical engineering is truly a commercial pursuit, for the field has reached its present magnitude solely through its money-making properties. This is borne out by statistics; for instance, in the year 1905, in the United States alone, apparatus and supplies were purchased to the extent of $210,000,000, and electric railway, lighting, power, telephone and telegraph industries yielded a gross revenue of $720,000,000. These figures are conclusive.

There are two primary branches in electrical work, namely, manufacture and utilization, and it is worthy of note that with a few brilliant exceptions, there are no engineers at the commercial head of these industries to-day. This is a condition which should not exist, for the engineer's education should broaden him and fit him for such responsibilities.

When a young man leaves his Alma Mater, with a diploma stating that he is this kind or that kind of an engineer, he usually has the firm conviction that his education is complete and that he is an expert in every sense of the word, whereas, it has been stated, by our good friend, Dr. Galbraith, I think, that a college can give a man a foundation of knowledge only, and that his real, his important education, does not commence until he is out in the world.

Some eight years ago, the Testing Department of the Sprague Electric Company frequently took in graduates from the New York universities. A few of these men were all right, but the great majority were almost hopeless. They did not seem able to grasp the idea that they were paid to get the work through the shop—they had large, cumbersome, and utterly impractical ideas on the commercial testing of motors and generators. These men may have known a good deal about the sciences of electricity, in fact some were not in the least backward in making statements to that effect, but they lacked utterly the commercial idea, and hence, so far as promotion was concerned, they were their own worst enemies.

I think the trouble lies in the fact that the young man in college is rather too apt to consider that things commercial are beneath his dignity, and I wish to say, therefore, with reference to this mistaken idea, that if he ever hopes to make money out of his profession, and this, I presume, is a rational desire, he will have to acquire early in his career a thorough grasp of the underlying principles of business.

When an engineer is assigned to a certain piece of work, he must appreciate the object of that work, and must know how to achieve that object with a minimum expenditure of time and money. In valuations, you may be able to inform a prospective buyer of all the technical characteristics of a certain machine, but he does not care about such things. He does not understand them and has no wish to, but he does want to know how much the machine is worth to him in money for the purpose he intends using it, what other machines of the same class have been sold for, and what market exists should he wish to re-sell. The capitalist who is desirous of entering into the business of electric lighting and power says: "Here is a city, and there, I understand, is a water power. Advise me on the possibility of establishing a plant." Your report under such circumstances must be simple and to the point, and must show a thorough understanding of the commercial end of this class of business. Otherwise it will carry no weight. If you insist upon including a long and complex dissertation on alternating vs. direct current transmission, your client must surely get the impression that such action is at the expense of the practical side of the situation.

Switchboard design is a matter upon which engineers are prone to spend money uselessly. The purpose of a switchboard is specific, and hence it must be simple, the incorporated apparatus must be reliable, and yet, withall, the first cost must be kept down to a minimum point. Complicated switchboards are a prolific source of accidents, both to persons and to apparatus, and hence for this reason alone, are things to be avoided. The earning power of a plant is in no way increased by the installation of an elaborate system of panels, and it is with earning power that we are concerned.

Young engineers are apt to worry uselessly over matters foreign to the subject in hand, and only practical experience can cure this evil. I remember some years ago when a small transmission system was being designed, the engineer became cognizant of the condition known as resonance. This bothered him considerably, for its possibilities appeared unlimited, and he really knew nothing about the subject. About this time an engineer of international reputation delivered a lecture on transmission, and among other questions he was asked what provisions he had found necessary for the prevention of resonance His reply was to the effect that he had never heard of any transmission line where trouble had been experienced from this source, and hence he did not bother much about it. When our young engineer heard this, he was much relieved, and very properly dropped the matter forthwith.

Short cuts have their place in business and hence in engineering calculation, and therefore, at this juncture, it will be well for us to give consideration to the slide rule, a very much abused, though decidedly useful instrument, Like the hand level, it is quick and fairly accurate, and consequently, in your commercial life, you will find it of great value. But do not try to make it accomplish things for which it was never intended—where accuracy is essential, fall back on pencil and paper, and use the slide rule as a check. Learn to use it carefully, but do not get the habit too badly. Remember that a man's brain is capable of making simple calculations. Mr. J. G. White once remarked that nothing annoyed him so much as to have one of his high-priced engineers pull a slide rule out of his pocket and say that two tons of steel rails at $33.00 per ton would cost approximately $65.00.

Too much attention to the scientific end, and too little to the business end, renders an engineer impractical, and hinders him in the proper handling of men. This is a most important matter, and without it the engineer can never become prominent in the commercial or "large salary" end of the art. He is bound to come into close personal contact with both his subordinates and his superiors, and his success depends to a great extent upon his ability to get along with these two classes.

It is in the selling of appartus that the business end of an engineer's education plays the most important part—really I think his very existence as a salesman depends upon his grasp of commercial principles, and also upon his knowledge of human nature.

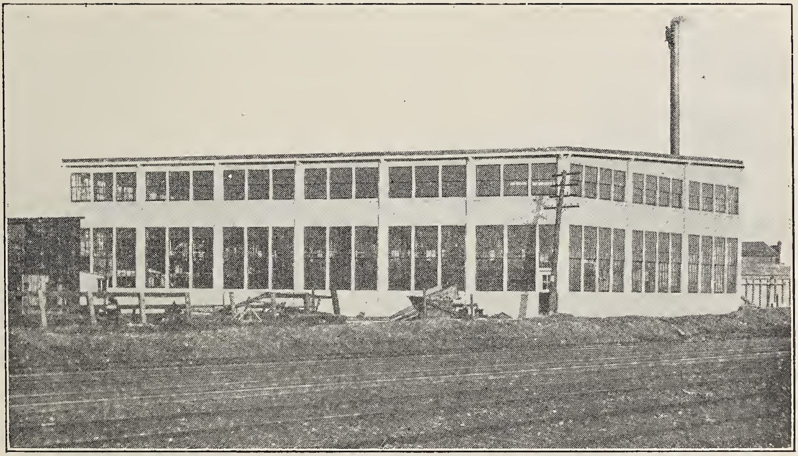
While I have this opportunity, I wish to give you my ideas on the subject of engineering training. My own opinion coincides with that of Dr. Galbraith, namely, that the college can supply the foundation only. You have the opportunity now of laying that groundwork well, and I can tell you honestly that if you neglect it in college, you will have no time to complete it after you commence to earn your living. Therefore, I say to you, devote every moment of your college course to the building of a foundation capable of sustaining the practical experience which will come to you in later years.

I believe that the last two years of the college course are of vast importance, and I think therefore that every student should fit himself, so far as it is in his power, to thoroughly appreciate the work of his third and fourth years. To this end I would say that the ideal education consists of two years of college, followed by an equal term in the shop of some large manufacturing concern. This latter period will instill, to a certain degree, a sense of the commercial fitness of things, and then when the third and fourth years of college have finished the foundation, the student will leave his university with a wholesome and proper idea of his own smallness, which, I assure you, is a very desirable state of affairs, after graduation. I think another year in the shops and a year of erecting work, will be found of great value. Then there should come, as a coping-stone, at least two years as a salesman, and if our student has been successful throughout all this miscellaneous work, we may safely say that he has found himself. He will seek responsibilities and acquit himself with credit, and he will appreciate the major importance of the commercial side of engineering, the side which I really believe is the backbone of the whole business.

*SOME FURTHER COSTS ON CONSTRUCTION OF CONCRETE FACTORY BUILDINGS

D. C. RAYMOND

In answer to your request that I submit additional data regarding labor in the erection of the McGregor, Banwell Fence Co.'s factory, the following information may prove of interest:



McGregor, Banwell Fence Co., Walkerville, Building Completed

Building runs, hoisting and mixing concrete—		
Engineer, 378 hours at 25c.	$ 94.50	
Laborers, 3826 hours at 17½c.	669.52	
Carpenters, 308½ hours at 35c.	107.98	
		$ 872.00
Placing and tamping concrete—		
Laborers, 3211½ hours at 17½c.		562.00
Placing reinforcement—		
Laborers, 1263 hours at 17½c.		221.00
Stripping centering, and cleaning up—		
Carpenters, 420 hours at 30c.	$126.00	
Laborers, 1451 hours at 17½c.	253.93	
		379.93

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*The receipt of two letters on about the same mail, one from New York, the other from San Fancisco, asking for the above information, showed not only how widely Applied Science is read, but convinced us that the information is desirable.—Editor.

Carpenters building and setting forms—		
Carpenters, 4700 hours at 35c.	$1,645.00	
Carpenters, 1212 hours at 30c.	364.50	
	———	2,009.50
Superintendence—		
Foreman, 44 days at $6.00	$264.00	
Company's supt., 2½ months at $100	250.00	
Engineer, inspecting, including traveling expenses re same	200.00	
	———	714.00

By an arrangement with the owners, we employed as many of their factory hands as possible at 17 1-2 cents an hour. Their former building was destroyed by fire and the firm desired to keep as many of their old hands employed as possible. The carpenters were paid 35 cents an hour, with the exception of a few at 30 cents.

I would like to call your attention to a typographical error in the former publication, under "Cost of Materials," the cost of centering, per cu. yd. should be $5.84.

APPLIED SCIENCE

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Editorial

Provincial Forestry Policy.

During the first week of this month the existence of the Faculty of Forestry has received a testimony of justification which will rejoice every forester's and every patriotic citizen's heart. It came in the shape of an announcement by the Honorable F. W. Cochrane, Minister of Lands, Forests and Mines, to the effect that the Ontario Government proposes to inaugurate a more rational and conservative policy regarding the treatment of the timber resources. We are glad to see that conservatism is taking up a proper line.

The programme laid down includes an extension of the fire ranging system, an increase in the force of forest rangers who supervise the cutting on timber limits, and an extension of the forest reservation policy. The timber in the forest reservations is to be cut under special regulations, which, we suppose, means that they are to be placed under proper technical management of foresters.

And another important step proposed is to settle the rights of the timber license holders. These have by misconstruction of their contracts with the Government contended that they are entitled to everything growing on their limits, and the Government must by compromise or otherwise regain possession of its property.

It is also proposed to foster the reforestation of waste lands in the older parts of Ontario, where farmers are suffering from dearth of timber. Even Dean Fernow could probably not suggest any further steps, except perhaps that a technically manned department should be instituted to carry out these plans ,in which his students would find employment.

We congratulate the Minister on his statesmanlike attitude to this, Canada's greatest interest, and the Faculty of Forestry on the likelihood of early recognition of its students in Government service.

Widening of Technical Education

We hear considerable discussion these days on the subject of technical education. Our Boards of Trade and Labor Unions are taking the matter up. They know they want something, they realize that something is lacking under present conditions, yet they do not appear to be able to agree on exactly what they do want. At the same time we have our own men criticizing the course. This arises mainly because they do not understand the exact conditions and limitations of Engineering education. Engineering schools have before them a field which may be divided into three parts, two parts being semi-professional or completely professional and the third vocational and subordinate to the others. Our School has only occupied one effectively, though there is a tendency towards an occupation of the second. The three fields might be defined as follows:

(a) Engineering Research and advanced professional instruction which is being given here and there to a few graduate students, and which is still in its infancy in Toronto.

(b) The Engineering courses of study as they are now ordinarily planned.

(c) The instruction of artisans and especially instruction adequate to the need of industrial foremen. It is a debatable question that the time has now arrived that the province should step in and train such men for the manning of our industrial enterprises. It might be noted in passing that this three-fold field is already covered in the work of the Agricultural College at Guelph. No one will deny that the money expended in any of the three portions has not been a splendid investment to the province.

Professor D. C. Jackson, of the Massachusetts School of Technology, in a paper read before the Society for the Promoting of Engineering Education, made the following statement:

"I lay this fact at the door of Engineering Schools and hold that the members of the Faculties are not guiltless unless they make adequate efforts to get filled this need in education for master craftsmanship in the industries which comes within the purview of their influence and direction."

The governing boards of the Engineering Schools must divide the guilt with the Faculties if they continue their common failure to provide sufficient teaching force in the Engineering department, thus putting any effort which reaches beyond the routine of the department record and touches the larger interests of the industrial body beyond the physical endurance of the individual members of the Faculty.

I believe that such views lead emphatically to the proposition that Engineering Schools are called upon to extend their influence so that they will continue their present work of education for the scientific engineer, advance the work of engineering research and advanced professional study, and also foster the establishment, maintenance and development of Polytechnic Schools for master craftsmen.

Culture in Technical Education

A contributor deals with the question of broadening the education of our graduates. He lays stress upon the personal training of the men. What he says cannot be easily denied. The graduate will find, more and more, after graduation that if he is to make a real success in life, he must deal successfully with men as well as with engineering problems. To do this, the better his mental equipment, the more certain is his success. In dealing with other men, it is undoubtedly what is called the personal equation that counts. Education cannot make a man, but it will develop him. Nine times out of ten it is not what a man knows, but what he is that makes the impression. No one will deny that knowledge is not absolutely essential, but it is only the power behind this knowledge which can produce the best results. We sometimes meet the unfortunate example of what has been termed the "walled-up mind" stored with facts but incapable of using them in any but a very narrow, restricted manner. For this reason a man is much better equipped who does not have to depend solely upon a technical training, no matter how good and well grounded. The breadth of view which comes from a general training has in every case its effect on those with whom we come in contact, and this in spite of the fact that those with whom we deal can very seldom put their finger on the exact reason why a strong influence is exercised.

SUGGESTED CHANGES IN THE CURRICULUM

D. J. McGUGAN, '07.

The present is marking an era of expansion for the University and this expansion, as is found to be the case with nations also, is exhibiting itself in an effort to better conditions that may be improved, wherever such opportunities may be found. The spirit of growth, with its attendant liberality of ideas, is in the air. The time is ripe for the institution of better methods and still higher ideals. But wherever any fundamental changes may be contemplated, the wisdom of making haste slowly is perceived and so any well-balanced discussion on anticipated changes can have nothing but a beneficial influence.

Dealing with our own Faculty of Applied Science more particularly, it is generally recognized that the student does not receive the full benefit of a Fourth Year. We recognize fully that one can get back only that which he puts into the Fourth Year, but whether through lack of confidence, or through lack of efficiency, it is no secret that, as at present arranged, the Fourth Year student has not the incentive to apply himself with the necessary energy to the particular branch in which he specializes. Then at the other end of our course, such a superfluity of work awaits the one of average intelligence that the only relief is found in what is familiarly termed cramming. Granted that such conditions exist, let us see how we may proceed that these difficulties may in part be remedied.

At present a large proportion of the students enter the School with Junior Matriculation. The father, understanding that such is the entrance required, and being urged on by the anxiety of the boy to enter the larger joys of college life, sends him to the School and imagines that at last the boy is safely embarked on the royal road. But any student who has entered the School under these conditions can testify how much work is represented by the First Year, with its bewildering array of mathematical and scientific subjects, all of which are, to the student, new lines of reasoning and new avenues of research. After the first glamor of boasting of all the newer branches of mathematics he is studying, has worn off, he finds much hard work ahead of him. Not that this is not a beneficial condition. Life is not all a bed of roses and the sooner a student acquires the ability of surmounting difficulties, the nearer is he to ultimate success. But since these elementary principles which are evolved in the First and Second Years form the very network on which the more advanced work and his subsequent engineering experience is built, he will, again and again, rue the fact that so much of his primary mathematics has slipped away.

As a remedy the raising of the entrance standard to Senior

Matriculation seems to suggest a very sensible and tangible relief. It will never be denied that the student can secure much more thorough training in mathematics at a collegiate institute than he can at a college, simply on account of the methods employed. Call it spoon-fed, if you will, but the fact remains that he has acquired such a grip on his mathematics that he can use the principles intelligently, and does not in an attempt to follow the mathematics involved in a lecture, lose the newer idea. Coming with this higher standard, he steps on surer ground, he attacks new branches with greater avidity and precision, and finding that all mathematics and science are an evolution, he assimilates much more of them, causing him to like the work, and liking the work, to become a greater success in it.

This standard would also bring the student nearer that age when he can appreciate the more the advantages of college associations and ideals. He has a wider view, a fuller outlook, a keener perception of the value of rubbing shoulder to shoulder with some of the cleverest and brightest men of our province. Nor is he alone benefitted. Indirectly the University receives its reward. The welfare of the College rests with the Faculty, the undergraduates and the graduates. The presence of a virile and intellectual student body must reflect itself in public opinion, and give our School a larger place in the development of our country.

Then comes the question of expense, whether is it wiser to spend an extra year at home in a collegiate or to lose a year in college where it costs much more? This of course does not apply to everybody, but the fact remains that a large number of the First Year fail every year, and I refuse to believe that the large proportion of these failures were of men who wasted so much time that success was impossible. There are examples of this, it is true, but let us not judge by isolated cases but by general conditions. It has been said that a certain number of students, any way, must fail in the First Year through lack of accommodation. Such a statement cannot be true. A pupil fails simply because he has not the requisite standing to take up subsequent work intelligently. Would it not be wiser to avoid the possibility of this by spending an extra year in the home collegiate?

It may be urged that this would bar a certain proportion of the students who come here. Perhaps it would exclude a few, to whom time and money is needful, who, by their industry, would be able to pass the First Year successfully any way, and I grant that the absence of such men would be a loss to the School. But to the general class of people, who appreciate the amount of work in the School, who are anxious to engage in engineering practice, such would be no bar, but simply a means to an end.

Then coming to the present status of the Fourth Year, mentioned briefly beforehand, the obvious remedy seems to be the enlargement of the course to four years, thus abolishing the present standing Grad. S.P.S. The work could be more evenly distributed over the four years. More work could be added in each particular line and more irrelevant work discarded. In my mind this is the only solution of the Fourth Year problem, simply because more stress would be laid upon it by the student and he could accomplish more useful work. At present there is not sufficient work in the last year. If a student only worked at the same pressure as he did during his Third Year, the amount of work could be done in much less time.

With a four-year course, it would be well to defer too great specialization until the last year, in which year he could engage more particularly in the line of work chosen. There would be greater opportunity for continuity in the work and a common goal for all, attention being paid of course to the particular needs of each department.

This would give an opportunity for the introduction into the course of the study of English. Lectures in Rhetoric would be directly beneficial to every engineer because he is called upon to give reports, to write articles and specifications and nothing detracts more from the value of the report or the personal prestige of the writer as the improper use of the rules of grammar. In order to tone down the exactitude of the course, I should like to see the introduction of the study and reading of some of our English masters. Such would be a recreation and a rest and would be appreciated greatly in after life if a desire for the better authors was inculcated. The different details can only be arranged by men of educational experience, but it is certain that the lack of a chance to acquire a more intimate knowledge of literature is one which is felt to be a distinct loss.

Should these changes be consummated, such an opportunity of evolving well-educated, well-balanced scientific men would be at our hand, that our School might easily rank with those of greatest fame either in the Old or New World. Our graduates might not necessarily be storehouses of data and facts, but men trained to perceive, to think, to judge and to act, men whose latent capabilities have been so drawn out and developed that they would be able to take their place in the world, to which their mastery of themselves entitled them.

Where opportunities to improve the curriculum exist, where there are grievances to be ventilated, the student does not do his duty to his Alma Mater if he remains silent. Shall we then allow to pass so great an opportunity to broaden the life of the School, and in so doing, to leave our lasting imprint for good on the development and civilization of our country?

THE COURSE IN ANALYTICAL AND APPLIED CHEMISTRY

MAITLAND C. BOSWELL, M.A., Ph. D.

The course in Analytical and Applied Chemistry in the Faculty of Applied Science of the University of Toronto, has been designed to give that training in the principles of the several branches of pure and applied chemistry, viz:—Inorganic, Organic, Analytical, Engineering, Industrial and Physical Chemistry, as well as that laboratory practice in elementary chemistry, qualitative analysis, gravimetric volumetric and optical quantitative analysis, inorganic and organic synthesis, gas analysis and electro chemistry which the best university practice, both on this continent and abroad, has adopted in similar courses.

It is also the custom of the department at Toronto to supplement in the fourth year this quite universal system of lecture and laboratory work, by the consideration of special subjects, in a more detailed way than is possible during the previous three years, bearing in mind the capabilities and needs, as well as the tastes and possible future work of each student. Thus one may be particularly interested in the coal tar products, another in the destructive distillation of wood industry, another in the manufacture of sugar, another in the analysis of iron and steel, another in the synthetic preparation of dye-stuffs, or any of the large number of important organic and inorganic industries and the methods of their laboratory control. The particular subjects to be studied having been decided upon, laboratory work and reading are assigned dealing with the mechanical and chemical details of the processes involved, their analytical control, and the investigation of problems relating to these industries whose solution would be of value.

Also recognizing the fact that much of the research work performed in technical laboratories deals with subjects of purely theoretical interest, problems of this character are also assigned to students who possess the qualifications for this kind of work. Apart from the value which his research may have as a contribution to science the work of investigation is of particular advantage to the student. It seems unavoidable, owing to the immense amount of information to be assimilated, that during the major portion of the undergraduate course of the student in any branch of science, he is constantly, in his lectures, in his reading, and in his laboratory work, having poured in upon him a mass of facts, the products of other minds, with very little opportunity of developing his own powers of independent thought and originality. As a consequence we sometimes meet the unfortunate example of what has been termed "the walled up mind," stored with facts, but incapable of using them in any but a very narrow, restricted manner. If the student of chemistry is to be other than a "hewer of wood and drawer of water" in his profession he must possess the power of giving expression to his stores of mechanical and chemical facts in some new form, in the solution of new problems whether they are met with in the department of pure science or applied science. Research work is one means of supplying this vital need of the student. It leads him into unknown parts, where he must think for himself and devise methods of overcoming difficulties, both mechanical and chemical. It familiarizes him with the original literature and with all the sources of information extending back to the time when chemistry began to be a science. This gives him a new point of view and causes him to assume a new attitude towards the subject as he realizes how its foundations have been laid and the superstructure raised to its present unfinished condition. Having had his patience taxed severely in overcoming the difficulties of his research he has a more sympathetic interest in the life history of the fathers of the science and a more hearty appreciation of what they accomplished.

The results of the reading and investigation are embodied in a thesis which is prescribed as partial fulfillment of the requirements for the Bachelor's degree. The titles of these theses for the present academic year are as follows:—

Mr. C. W. Graham—Laboratory methods of organic chemistry and the synthesis of Iodine derivatives.

Mr. Fux—Sugar manufacture and Analytical control.

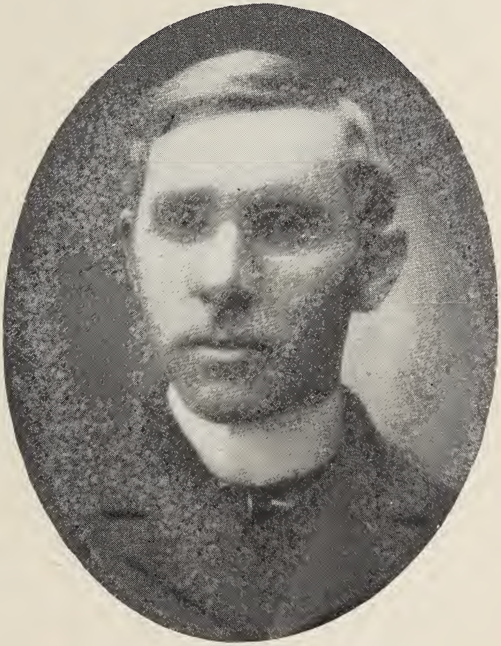
Mr. Mason—The destructive distillation of wood.

Mr. Beynon—The investigation of a new method of treating the caustic liquor form the soda process of paper manufacture.

Following is a short statement of research work being pursued by some of the advanced students. Mr. C. W. Graham is synthesizing a series of new iodine derivatives having as his objective tetraiodorthobenzoquinone and its derivatives, Mr Beynon is working on the nitrosate method for the quantitative estimation of rubber and combined sulphur in commercial rubbers and a new method for treating the caustic liquor from the soda process of paper manufacture. Mr. Fux is studying the methods of analysis used in the control of sugar manufacture. Mr. Mason is investigating some commercial products of the destructive distillation of wood of unknown composition. Mr. Huether is synthesizing typical examples of several classes of dye-stuffs and will carry out on a laboratory scale the industrial process of applying them to fibres. Mr. Rothwell is working on a new method of determining carbon monoxide. Other subjects of research which will receive early attention are—the action of stannous chloride on alpha naphthoquinone. The direct quantitative determination of oxygen in organic compounds, for which no practicable method is as yet known, a new method of estimating Phthalic acid, and methods of making some inorganic separations by means of organic reactions.

WHAT THE GRADUATES ARE DOING

Our Contributors



Mr. Charles H. Mitchell

Charles H. Mitchell was born at Petrolea, Ontario, February 18th, 1872; and is the eldest son of Rev. George A. Mitchell, B.A., Methodist minister. He matriculated to Toronto University in 1888, graduating from the School of Practical Science in 1892. Granted postgraduate degree of B.A.Sc. (Bachelor of Applied Science) 1894; and C.E. (Civil Engineer), 1898. His career began as Assistant City Engineer at Niagara Falls, N. Y., 1892-3; engaged on special work in water-works and water-power construction and trunk sewer tunnels in rock From 1894 to 1901 he was in private practice at Niagara Falls, Canada, and during this period designed and superintended construction of the following works: Municipal — Sewer system, brick pavements, and waterworks for Niagara Falls, Ontario; also bridges for County of Welland; Power Work—The hydraulic plants at Bracebridge, Fenelon Falls, Orillia, Merritton, Wahnipitae, and St. Catharines, together with minor works, and improvements to existing plants. Also made reports, plans and estimates of projected hydraulic power plants in Ontario, Quebec, Maritime Provinces and New York State. From 1901 to 1905 was Chief of Mechanical Department of the Ontario Power Company of Niagara Falls, Canada; in charge of detail, design, and construction of Civil, Hydraulic, and Mechanical portions of this famous hydro-electric installation; probably the finest in existence. In December, 1905, sailed for Europe, and during an eight months' tour, inspected critically upwards of forty Hydro-Electric plants in France, Italy, Austria, and Switzerland, also numerous steam electric power installations in Germany and Britain. Has held Captain's Commission in Canadian Militia since 1899—first in Infantry and later in Corps of Guides. And is a member of Toronto University Senate (since 1901) representing graduates in Applied Science and Engineering. In autumn of 1906 established an office in the Traders Bank Building, Toronto, as consulting engineer, specializing in Hydro-Electric Power Engineering, with its allied branches. He is engineer for several power plants in Western Canada and has lately reported on numerous works throughout the Dominion.

Among those of our graduates who have attained warked success in the field of Bridge and Structural Engineering is Mr. D. C. Tennant, B.A.Sc., A. M. Can. Soc. C. E.—a contributor to this number of APPLIED SCIENCE.

Mr. Tennant's school and college days were spent in Toronto —his native city. With the enviable distinction of a double scholarship, one granted by the Public School Board and one by the High School Board, he finished his primary school days at Ryerson and entered Harbord St. Collegiate Institute. After thorough preparation here, he enrolled at the School of Practical Science in the Department of Civil Engineering, graduating with the class of '99 and taking his degree in '00, with honors in each instance. While in the post-graduate year, Mr. Tennant made an original experimental investigation of the tensile strength of rivets and bolts which received high commendation from several prominent engineers. Though conspicuously successful as a student, he did not rest upon his well-earned laurels, but sought practical experience in every posible way. Two summers were spent in the City Engineer's Department, Toronto, and one with the New Jersey Steel and Iron Co., Trenton, N.J., on general bridge and structural work. In 1900 he entered the employ of the Dominion Bridge Co., Lachine, P. Q., actin for a short time as draughtsman and afterwards as checker and supervisor of a large section of the detailing office, which latter position he holds at present. During these eight years, Mr. Tennant has been engaged in many important works, among which might be mentioned the Fraser River Bridge at New Westminster, B.C., the Cap Rouge Trestle, described in the present issue, and many other works of considerable magnitude for the National Transcontinental Railway. Mr. Tennant is now in immediate charge of about two-thirds of the detailing office staff, being ultimately responsible for the work of some 35 draughtsmen and checkers, and in the absence of Mr. R. B. Kenrick, acting as Chief Draughtsman. With the thorough grounding of years of experience and the oft-expressed assurance of his associates that "nothing is too big or too little for Tennant to handle," we predict eminence in the engineering world for the subject of our sketch.

ENGINEERING ALUMNI DINNER

It is almost a universal rule to describe all dinners as successes, therefore in order to describe this one it must be termed an unqualified success. It was remarkable in many respects, as will be dwelt on later. The usual order of things was reversed, the dinner being merely an incident, every one being interested in the object for which it was held. It was a very informal affair, being held at 6 o'clock at the St. Charles Hotel on Thursday, March 12th.

It was the result of several small meetings held previous to the above date. All the graduates in Engineering of the University of Toronto resident in and around the city were notified and requested to attend. The business started at 7 o'clock. Mr. C. H. Mitchell, '92 Faculty Representative on the University Senate, took the chair and K. A. MacKenzie, '06, was appointed secretary. There were altogether 85 graduates present ranging from the classes of '88 up to 1907, and of the number about 35 are now in attendance in the fourth year course at the University.

The primary business of the meeting was to confirm preliminary arrangements already entered into to obtain a portrait of Dean Galbraith, to be presented to the University, and to be hung in Convocation Hall. Some time previously the consent of Dr. Galbraith was obtained and an acceptance from President Falconer was also given for the portrait when completed to hang with other similar portraits, and the preliminary arrangements were made with Mr. J. W. L. Forster, artist, of Toronto, to execute the commission.

Letters from Messrs. Stern and Alison, representing the graduates resident in New York, and Mr. Speller of those in Pittsburg, were read to the meeting, and the fact that a movement in these cities, simultaneous with that in Toronto re the portrait had taken place, was received with applause by those present.

It was thought fitting by some graduates present that some similar tribute should be made to Dr. Ellis, who has been a lifelong co-worker with Dr. Galbraith in the upbuilding of the former School of Practical Science, and what is now the Faculty of Applied Science and Engineering. Numerous suggestions were made and discussed along these lines, with the final result as embodied in the motion indicated below.

It was strongly felt by all present that a movement should be shortly inaugurated to found a Scholarship in Engineering, to be applied to research work along particular branches, and while a good many opinions were advanced, the question of ways and means, particularly at this time, seems to be the greatest obstacle. This matter was left over for consideration at a later time in the year.

The formation of an Alumni Association was discussed at length but the opinion seemed to be that such was not necessary in Toronto because of the far-reaching influence and work of the Engineering Society, and especially since its recent close connection with the Faculty itself, whereby a paid officer takes up the duties of what would be mainly the object of an Alumni Association, in keeping in touch with graduates and their work. This work is now being further extended by the monthly publication of the Applied Science Journal by the Society. Great satisfaction was displayed at the formation of an Alumni Association in New York, Pittsburg and Winnipeg and the hope expressed that others would follow.

Considerable discussion arose as to the manner in which the graduates could assist the Faculty in its new status in the University as a whole, and especially as to the efficiency of the fourth or post-graduate year. It was pointed out, however, that many improvements and additions were in immediate contemplation in this work, especially in Hydraulics and Thermodynamics, and when the new buildings and equipment as contemplated are completed, the Faculty will have one of the finest equipments on the continent. The overcrowding of the different buildings used by this Faculty is a most serious matter at the present time, there being upwards of 700 students in Applied Science and Engineering. These conditions, without adequate extension of buildings and equipment or teaching faculty, seriously decreases the efficiency and hence arises the principal criticism.

A resolution was carried unanimously appointing a committee of five,. namely, Messrs. C. H. Mitchell, '92, A. F McCallum, '93, A. E. James, '04, K. A. MacKenzie, '06, and T. H. Hogg, '07, which had already been acting, to add six others resident in Canada to their numbers, and to act in conjunction with a committee from the United States, consisting of Messrs. E. W. Stern, '84, T. Kennard Thompson, '86, T. H. Alison, '92, H. F. Ballantyne, '93, of New York, and F. N. Speller, '93, and A. R. Raymer, '84, of Pittsburg. This committee is to form a permanent committee for the year representing the graduates, and in doing so is asked to secure the portrait of Dr. Galbraith, and also to purchase some suitable gifts for personal presentation to Dr. Galbraith and Dr. Ellis. It is also asked to consider the question of scholarships, and to take means to urge the importance of research work in the Engineering Faculty along the lines suggested at the meeting. It was thought that the portrait should be presented formally to the Governors of the University at the inaugural meeting of the Engineering Society in October next, and that the other presentations should take place at a dinner to be held in Toronto shortly before Christmas next, at which as many graduates as possible from all parts of the continent should be urged to be present.

Greetings were sent from this meeting to fellow-graduates in New York, Pitsburg and Winnipeg.

It is to be noted that the enthusiasm of this meeting was very marked and that in the hour and a half consumed in speeches, twenty of the graduates present spoke, and that thirty-four speeches were made by them.

As to the probable financial arrangements suggested to be followed out by the committee, it is likely that each graduate will be asked for a subscription of $2.00. The third and fourth years of the under-graduates have guaranteed at least $100.00 through the president of the Engineering Society, an announcement of which was made by Mr. Hogg at the meeting. It is thought that the proceeds of such arrangements will be amply sufficient to provide for needs. In all between eight and nine hundred dollars will be required.

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Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 21 MARCH, 1908 New Series Vol. 1, No. 5

BRIEF SYNOPSIS OF THE COURSE OF LECTURES IN ANALYTICAL AND GRAPHICAL STATICS

As Arranged for the First Year.

C. H. C. WRIGHT, B.A.Sc.

Sub-Divisions of Mechanics.—The subject of Mechanics may be sub-divided into Kinematics, Statics and Dynamics. Kinematics treats of motion only; Statics, of force only; and Dynamics, of both force and motion.

Force—A force is that which moves or tends to move, or which changes or tends to change the motion of any body; e.g., the attraction of the earth or the expansion of steam, etc.

The elements which specify a force are (1) Magnitude (as 10 pds.); (2) Direction (as vertical); (3) Sense (as upward); and (4) Point or line of application.

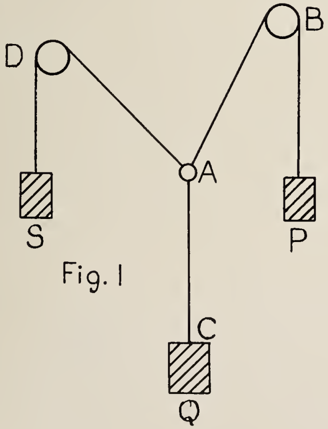

Fig. 1

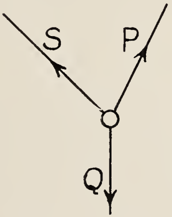

Fig. 2

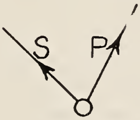

Fig. 3

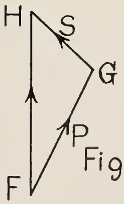

Fig. 4

Vector Quantity.—A Vector is any quantity which has magnitude, direction and sense; e.g., force, displacement, acceleration, etc.

As a finite straight line with an arrow-head has magnitude, direction and sense, it may represent any vector quantity.

Vector Polygon.—If from any initial point, a set of lines be drawn to represent a series of vector quantities in such a manner that their senses are continuous, they will form a polygon known as a vector polygon.

The line joining the initial to the final point (with the sense from the initial towards the final point) will represent the resultant. When the vector quantities are forces, the closing line of the vector polygon represents the resultant force; i.e., the single force capable of producing the same effect as the set of forces. The proof of the above is experimental.

Experimental Proof.—Fasten three strings, *AB*, *AC* and *AD* together at the point *A*, as indicated in Fig. 1.

Pass the string *AB* over a frictionless pulley and attach the end *B* to a known weight *P*. Similarly, pass *AD* over a second pulley and fasten the end *D* to a known weight *S*. Fasten the end *C* of the string *AC* to a known weight *Q*.

Now, let the system adjust itself and the point *A* come to rest. The knot *A* is acted on by three forces (caused by the tensions of the three strings) of magnitude *P*, *Q* and *S*, directions parallel to the three strings, and senses as indicated in the accompanying diagram (Fig. 2).

Now discuss the two forces *P* and *S* as in Fig. 3.

Draw the vector polygon *FGH* where *FG* represents the force *P* and *GH* — *S*. The line *FH* must then represent the resultant.

If the experiment indicated were performed and the vector polygon drawn to scale, the line *FH* would be vertical and its length represent the magnitude *Q*. This being true, it is obvious that a single force represented by *FH* might be applied to the knot *A* instead of the two forces *P* and *S*, and leave the point in a condition of rest; i.e., the resultant of *P* and *S*, as determined by the vector polygon, produces the same effect on the point *A* as the original forces.

Equilibrium.—A set of forces is said to be in equilibrium when they do not move or tend to move, nor change nor tend to change, the motion of the body upon which they act. Their resultant is, therefore, 0, and the final point of the vector polygon for such a set of forces must coincide with the initial point.

A weight of 12 lbs. is fastened to a string attached to a peg. A second string is tied to the first between the peg and the weight, and pulled horizontally until the part of the first string above the second makes an angle of 60° to the horizontal. Determine the tensions of the strings.

The annexed diagram (Fig. 5) represents the above condition. Consider the forces acting on the knot. There are three as illustrated in Fig. 6: (1) The pull *AB* of the vertical string; (2) the pull *BC* of the horizontal string; and (3) the pull *CA* of the inclined string. Draw the vector polygon *ABC* (Fig. 7) for these three forces. As they are in equilibrium, the vector polygon closes and *BC* and *CA* of the vector polygon represent the forces *BC* and *CA*. To obtain the magnitudes of these forces, measure the lengths of the sides of the vector polygon. Because the angles *B* and *C* are 90° and 60° respectively, and *AB* represents a force of 12 pds., therefore *BC* represents a force of $4\sqrt{3}$ pds., and *CA* of $8\sqrt{3}$ pds.

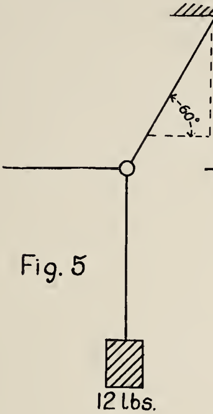

Fig. 5

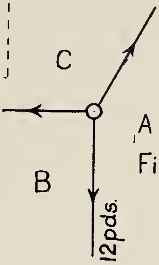

Fig. 6

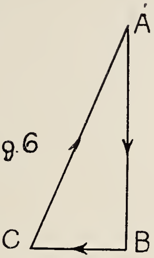

Fig. 7

Cantilever.—Let the accompanying diagram (Fig. 8) represent a cantilever supporting a load of *W* lbs. It is required to find the stresses in the various members of this truss.

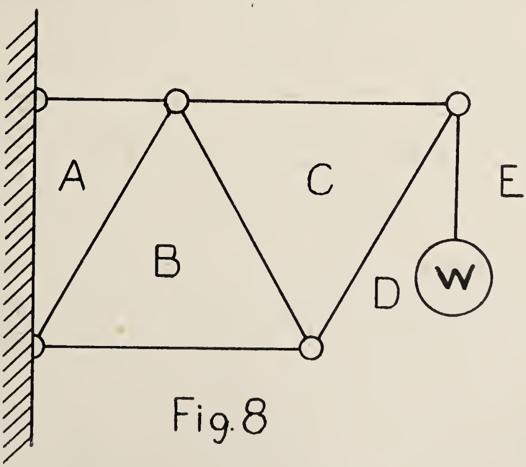

Fig. 8

Consider first, the forces acting on the point *CDE* (Fig. 9). There are three forces: (1) The vertical pull of the member *DE* (*W* pds.); (2) a force caused by the member *CD*; (3) a force caused by the member *CE*. The magnitudes and senses of the latter two forces are unknown; but, their directions are those of the members *CD* and *CE* respectively. From the point *D* (Fig. 10) draw *ED* to represent the known force *ED*; and through *E* and *D*, draw *EC* and *DC* parallel to the direction of the two unknown forces. These lines will intersect at the point *C*, and the vector polygon for the three forces then reads *ED, DC, CE,* and the lines *DC* and *CE* represent the forces *DC* and *CE* completely. Hence the member *DC* pushes on the point and is in compression to the extent of $\frac{2\,W}{\sqrt{3}}$ pds., and the member *CE* in tension to the extent of $\frac{W}{\sqrt{3}}$ pds.

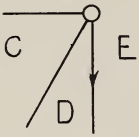

Fig. 9

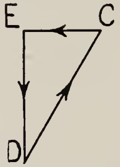

Fig. 10

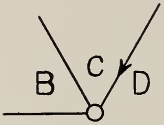

Fig. 11

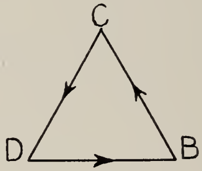

Fig. 12

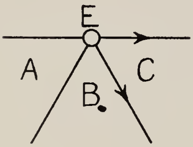

Fig. 13

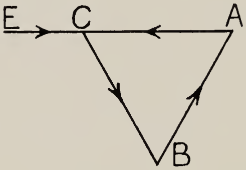

Fig. 14

Similarly, Fig. 11 represents the forces acting on the point *BCD*, and *CDBC*, (Fig. 12), the vector polygon gives the magnitude and senses of the unknown forces *DB* and *BC*. Hence, the member *DB* is in compression to the extent of $\frac{2W}{\sqrt{3}}$ pds. and the magnitude of the tension in *BC* is $\frac{2W}{\sqrt{3}}$ pds. The forces acting on the point *ECBA* are illustrated in Fig. 13 and the vector polygon for them in Fig. 14. Hence, the compression in *AB* is $\frac{2W}{\sqrt{3}}$ pds., and the tension in *AE*, $\frac{3\,W}{\sqrt{3}}$ pds.

Resolved Parts.—If two forces *P* and *Q* have a resultant *R* they are called the components of *R*. When their directions are at right angles to each other they are called the resolved parts of *R*.

The algebraic sum of the resolved parts of any set of forces in any direction is equal to the resolved part of their resultant in the same direction.

$$\Sigma X = X_R \quad \Sigma Y = Y_R.$$

Moment.—The moment of a force about a point is the product of the magnitude of the force, and the perpendicular distance of the point from the force, and is positive or negative as the force tends to turn the body on which it acts about the selected point, with or contrary to the hands of a watch.

Let P and Q (Fig. 15) represent two known forces, and A any point. It is required to prove that the algebraic sum of the moments of P and Q about A is equal to the moment of their resultant about A.

$M_P + M_Q = M_R$
$\Sigma M = M_R$

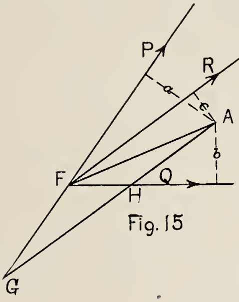

Fig. 15

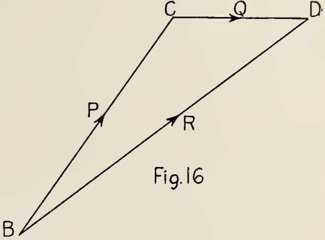

Fig. 16

Draw the vector polygon BCD (Fig. 16). The resultant will be represented by BD, and will act through F, the intersection of P and Q. Through F draw a line parallel to BD. Through A draw a line parallel to the resultant, intersecting the directions of P and Q at G and H. The Δ *le GFH* may then be considered as a vector polygon for the three forces P, Q and R. From A, drop perpendiculars a, b and c on P, Q and R. Join AF.

$$M_P = +P \times a = +GF \times a = +2\times \text{ area of } \Delta\, le\ GFA;$$
$$M_Q = -Q \times b = -FH \times b = -2\times \text{ area of } \Delta\, le\ FHA;$$
$$M_P + M_Q = +\,2\ le\ GFA - 2\ \Delta\, le\ FHA = +2\ \Delta\, le\ GHF$$
$$= HG \times c = +R \times c = M_R$$

Hence, $M_P + M_Q = M_R$.

As this is true for two forces, it is true for any number of forces, i.e., the algebraic sum of the moments of a set of forces about any point is equal to the moment of their resultant about the same point, or

$$\Sigma M = M_R.$$

Method of Sections.—Consider the truss illustrated in Fig. 17 as a rigid body, and take moments about the point NDF. The forces acting on this rigid body are DF, FG, GH, HA, AB, BC

and CD. Because they are in equilibrium $\Sigma\ M = 0$, therefore

$$DF \times 0 - 1200 \times 10 - 1200 \times 20 + HA \times 30$$
$$- 600 \times 25 - 600 \times 15 - 600 \times 5 = 0$$

or $HA \times 30 = +63000$

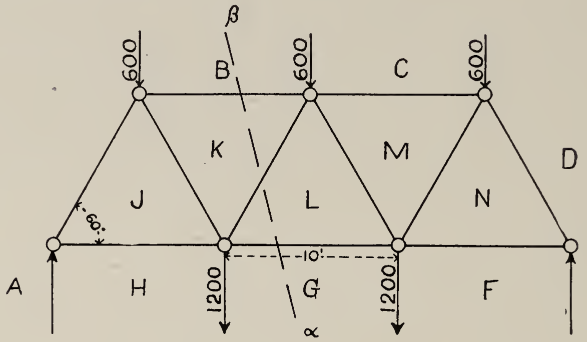

Fig. 17

Hence, $HA = 2100$

Again, because $\Sigma\ Y = 0$,
therefore, $+HA - 600 - 1200 - 600 - 1200 - 600 + DF = 0$
or $DF = 2100$.

Let the plane $\alpha\beta$ cut the truss as indicated, the consider the portion of the truss to the left as a rigid body. The forces

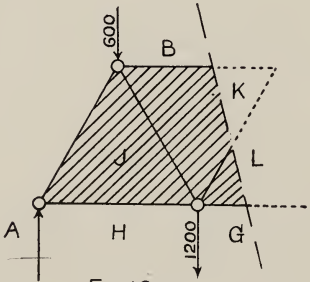

Fig 18

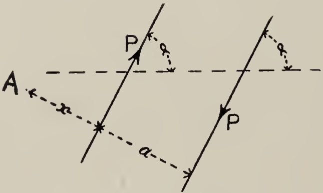

Fig. 19

acting on this rigid body are GH, HA, AB, BK, KL and LG, as indicated in Fig. 18. Because these forces are in equilibrium
$\Sigma\ Y = 0$
therefore $- 1200 + 2100 - 600 + 0 + Y_{KL} + 0 = 0$
therefore, $Y_{KL} = - 300$ pds.
that is, $KL \sin. 60° = - 300$
or $KL = -200\sqrt{3}$ pds.

This —ve sign means that the portion of the member KL to the right of $\alpha\beta$ is pushing on the part to the left, and the member KL is, therefore, in compression, the magnitude of the compression being $200\sqrt{3}$ pds.

Again, $\Sigma M = 0$

Take moments about the point $GHJKL$

$$1200 \times 0 + 2100 \times 10 - 600 \times 5 + BK \times 5\sqrt{3} + KL \times 0 + LG \times 0 = 0$$

$$BK = -1200\sqrt{3}$$

This —*ve* sign means that the moment of BK is —*ve*, and BK, therefore, has a sense towards the left. The member BK is, therefore, in compression to the extent of $1200\sqrt{3}$ pds.

Again $\Sigma X = 0$

therefore, $0 + 0 + 0 + X_{BK} + X_{KL} + X_{LG} = 0$

$-1200\sqrt{3} - KL \cos. 60° + LG = 0$

therefore, $LG = 1200\sqrt{3} + 100\sqrt{3} = 1300\sqrt{3}$

hence, the member LG is in tension to the extent of $1300\sqrt{3}$ pds

Fink Roof Truss.—For the solution of the Fink Roof Truss, see Transactions of the Engineering Society, No. 17.

Wind Pressure.—$v = \sqrt{2gh}$

$$p = h \times \text{(the wt. of a unit of vol.)}$$

therefore $v^2 = \dfrac{2gp}{\text{(wt. of unit of vol.)}}$

or $p = \dfrac{v^2}{2g}\text{(wt. of unit of vol.)}$

In the above, it is customary to use the foot and the second as the units of measurement; but the velocity of the wind is usually expressed in miles per hour.

When V represents the velocity of the wind in miles per hour

$$v = \frac{V \times 5280}{60 \times 60}$$

therefore $p = \dfrac{V^2 \times 5280^2 \times \text{wt. of a cub ft. sf air}}{60^4 \times 2g}$

One cubic foot of air at 60° and 760 mm. weighs 0.078 lbs. For a maximum value, take 0.1 lbs. as the weight of a cubic foot of air, and the equation becomes

$$p = \frac{V^2 \times 5280^2 \times 0.1}{60^4 \times 64} = .0033\,V^2.$$

Hence, the pressure in pds. per square foot on a surface at right angles to the direction of the wind, is given by the equation $p = .0033V^2$ where V is in miles per hour.

The observed values of Prof. Marvin show $p = .004V^2$, while those of Mr. Langley give $p = .00315V^2$.

If the pressure on a surface inclined to the direction of the wind be proportional to the number of particles of air impinged on its surface, then $p' = p \sin. a$ where p' is the pressure perpendicular to the plane, in pds. per sq. ft., when the plane is inclined to the horizontal at an angle α, the wind being horizontal. Therefore,

$$p' = .0033\ V^2 \sin \alpha.$$

Couple. $\Sigma X = 0$; $\Sigma Y = 0$; $\Sigma M = C$.—When two forces of equal magnitude have parallel directions and opposite senses, as indicated in Fig. 19, they are called a couple.

$$\Sigma X = +P \cos.\ \alpha - P \cos.\ \alpha = 0$$
$$\Sigma Y = +P \sin.\ \alpha - P \sin \alpha = 0$$

Take moments about any point A,

$$\Sigma M = -Px + P(x + a) = +Pa.$$

As both P and a are constant, the moment of a couple about any point is constant and is equal to the product of one of the forces and the perpendicular distance between them.

Graphical Determination of Resultant Force.—Let P, Q and S represent three forces acting on a rigid body in one plane, as indicated in Fig. 20. Draw the vector polygon $ABCD$, as in Fig. 21; then AD will represent their resultant in magnitude, direction and sense. Select any point O and join O with A, B, C and D. Select any point F in the line of direction of the force P, and at F, imagine P to be replaced by a pair of components represented by AO and OB. Produce the direction of OB to intersect that of Q at G, and at G imagine Q to be replaced by its components BO and OC. Produce the direction of OC to intersect S at H, and at H imagine S replaced by its components CO and OD. Now, the original forces P, Q and S have substituted for them their equivalents in AO, OB, BO, OC, CO and OD. Two of these six forces, OB and BO act with equal magnitude and opposite senses in the same direction, and are, therefore, in equilibrium. Similarly, OC and CO are in equilibrium. Hence, AO acting at F and OD acting at H are equivalent to the original

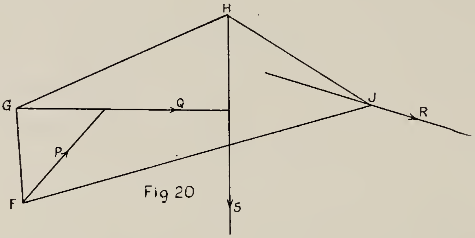

Fig 20

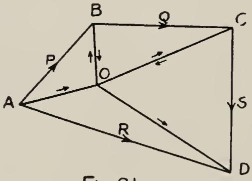

Fig.21

forces. The resultant of AO and OD will act, through their intersection J. Hence, R the resultant of P, Q and S must act through J.

Funicular Polygon.—The figure $FGHJ$ is called the funicular polygon.

General Conditions.

Analytical	Graphical
$\Sigma\ X = X_R$ $\Sigma\ Y = Y_R$	Vector polygon gives the Resultant
$\Sigma\ M = M_R$	Funicular Polygon gives the position of the Resultant

Conditions of Equilibrium.

$\Sigma\ X = 0$ $\Sigma\ Y = 0$	Vector Polygon closes.
$\Sigma\ M = 0$	Funicular Polygon closes.

Couple.

$\Sigma\ X = 0$ $\Sigma\ Y = 0$	Vector Polygon closes.
$\Sigma\ M = C$	Funicular Polygon open.

The Simple Horizontal Beam.—Let the annexed diagram (Fig. 22) represent a simple, horizontal beam resting on two supports and carrying a load of W lbs., distance k from the left abutment A. Imagine a vertical plane $\alpha\beta$ distant x from A.

V. S. F.—The vertical shearing force (V. S. F.) at any plane is, by definition, the algebraic sum of the external forces acting on the beam to the left of the plane.

When $x < k$, the V. S. F. at $\alpha\beta = +A = \frac{l-k}{l}\ W$.

Similarly, when $x > k$, the V. S. F. $= +A - W = -\frac{k}{l}\ W$.

Hence, the ordinates to the lines CD and FG (Fig. 22) represent the values of the V. S. F.

B. M.—The bending moment (B.M.) at any plane $\alpha\beta$ is the algebraic sum of the moments of the external forces to the left of the plane about any point in the plane.

When $x = 0$, B.M. $= 0$

When $x < k$, B.M. $= +Ax$, and may be represented in Fig. 21 by the area of the rectangle CH.

When $x > k$, B.M. $= A \times x - W\ (x - k) = A \times k - W \times \frac{k}{l}(x - k)$ and may be represented, in Fig. 22, by the rectangle CJ — the area of the rectangle FL; i.e., the area of the V. S. F. diagram to the left of any plane $\alpha\beta$ represents the B. M.

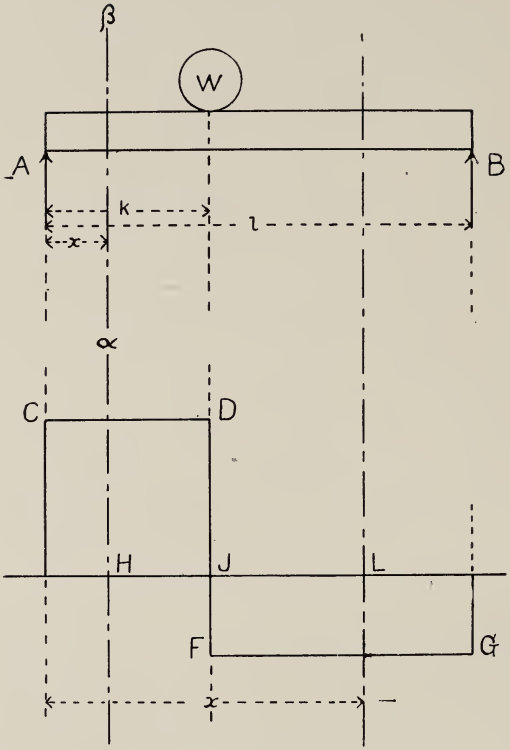

Fig. 22

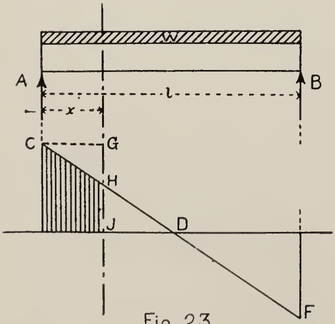

Fig. 23

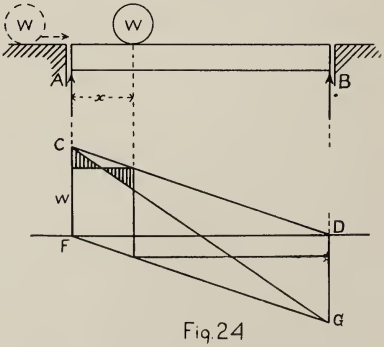

Fig. 24

Let Fig. 23 represent a horizontal beam supporting a uniformly distributed load of W lbs. The V. S. F. at any plane $\alpha\beta = +A - \frac{x}{l} W = + \frac{W}{2} - \frac{x}{l} W$

When $x = 0$, V. S. F. $= + \frac{W}{2}$

When V. S. F. $= 0$, $x = \frac{l}{2}$

Hence, the ordinates to the line CDF will represent the Vertical Shearing Forces.

The B. M. at any plane $\alpha\beta = A.\,x - \frac{x}{l}.W.\,\frac{x}{2}$

$$= \frac{W}{2}\,x - \frac{W}{2\,l}\,x^2$$

The B. M. at $\alpha\beta$ may be represented by the area of the rectangle CJ less the area of the triangle CGH or by the area of V. S. F. diagram to the left of $\alpha\beta$.

Live Load.—As the load W moves across the beam from A to B (Fig. 24), let x represent the distance of the load from A.

The V. S. F. to the left of the load $= +\,A = \frac{l-x}{l}\,W$.

When $x = 0$, V. S. F. $= +W$.

When $x = l$, V. S. F. $= 0$.

When the load is at a distance x from the left abutment, the V. S. F. to the left of the load will be represented by the ordinate of the line CD directly under the load.

Similarly, the V. S. F. to the right of the load $= +A - W$

$= -\frac{x}{l}.W$

When $x = 0$, V. S. F. $= 0$.

When $x = l$, V. S. F. $= -W$.

Hence, the ordinates of the line FG will represent the V. S. F. to the right of the load.

Join CG and the B. M. at $\alpha\beta$ distant x from A, when W is at $\alpha\beta = +Ax = +\frac{l-x}{l}\,Wx$.

Therefore, the area between the line CG and the axis of X to the left of $\alpha\beta$ represents the B. M. The maximum B. M. will occur at the centre of the beam when the load is over that point.

The Ordinates of the Funicular Polygon represent the Bending Moments.—Let the annexed diagram (Fig. 25) represent a horizontal beam supporting four loads. Draw the vector polygon ABC, etc. Next, draw the funicular polygon, FGH, etc. As the forces are in equilibrium, the funicular polygon closes. Hence, the direction of the line FP and the point L in the vector polygon. Now, draw the V. S. F. diagram, the areas in which will also represent the B. M.

Let $\alpha\beta$ be any plane between the loads AB and BC. Let it intersect the funicular polygon at the points J and K. The forces acting on the portion of the beam to the left of $\alpha\beta$ are LA and AB. The algebraic sum of their moments about any point in $\alpha\beta$ is equal to the moment of their resultant about the same point; but, the resultant of these forces is represented by LB in

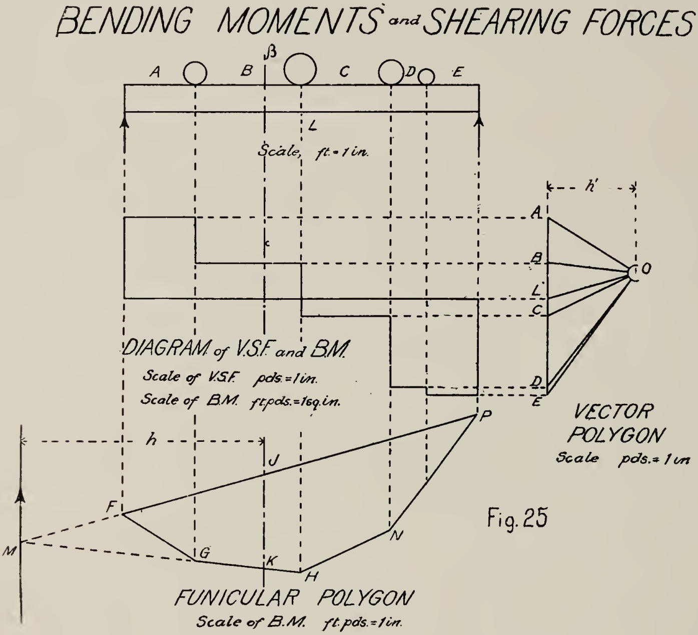
BENDING MOMENTS and SHEARING FORCES
β
A
B
C
D
E
L
Scale, ft.=1 in.
h'
A
B
O
L
C
D
E
DIAGRAM of V.S.F. and B.M.
Scale of V.S.F. pds.=1 in.
Scale of B.M. ft.pds.=1 sq.in.
P
VECTOR POLYGON
Scale pds.=1 in
h
J
F
M
G
K
H
N
FUNICULAR POLYGON
Scale of B.M. ft.pds.=1 in.

Fig. 25

the vector polygon and acts through the point M as given by the funicular polygon. Now, the Δ *le* JMK is similar to the Δ *le* LOB. Hence, $KJ \times h' = LB \times h$; but, $LB \times h =$ the B. M. Therefore, KJ, the ordinate of the funicular polygon may represent the B. M. and the scale of B. M.'s will be the scale of forces $\times$ the scale of length $\times$ h'.

In addition to the work indicated by the above synopsis, the values of the V. S. F.'s and B. M.'s are determined for a series of moving loads (the engine diagram), and the following are discussed at some length: friction, the inclined plane, the pulley and the windlass.

The stresses in the members of the following trusses are also determined: Cantilever, King Post, Queen Post, Howe, Pratt, Warren, German Roof Truss, French Roof Truss, and Fink Roof Truss.

*MATHEMATICS OF TREE GROWTH

B. E. FERNOW

Dean, Faculty of Forestry

It is of course generally known that trees grow in height by adding story upon story of annual shoots which arise from buds, and in girth or diameter by adding layer upon layer of wood, cornucopia-like, upon the wood of the preceding years; the cambium layer of cells, lying between the bark and the wood, giving off wood cells and bark cells, and thus increasing the girth. This layer of cambium cells represents the principal living portion of the tree, for the wood, the deposit of annual layers, which on a cross-section appears as the familiar annual rings, is mostly dead material, an accumulation of cells and tissues that have lost their protoplasmic contents and their ability to divide and grow.

The botanist studies *how* trees grow, but the forester goes a step farther and inquires *how much* trees grow; the quantity or amount of their performance—their increment, their "yield," is his main interest. Through laborious measurements and classification of his results he has succeeded in recognizing and formulating the laws of growth in quantitative direction.

The fact not only that the increment in girth takes place by defined annual additions, but that by the difference in structure of the initial or spring wood, formed in the beginning of the season, and of the later-formed summer wood, each annual ring can be recognized as such—these facts permit us to relate increment to time, and to study the quantitative performance from year to year, or from period to period on a cross-section as functions of time. By stem analysis, as the forester calls the operation, the whole history of growth of the tree in height, diameter, form (i.e. diameter at different heights) and volume, is revealed; and from its behavior, or rather from the measured average performance of many trees grown under similar conditions, the behavior of others of the same species under the same conditions may be predicted. The methods of measuring have developed into a technical discipline, "forest mensuration," which forms one of the important equipments of the forester. Here I may only hint at the method of unravelling this history of tree growth. It is done by cutting full-grown trees into sections of three to six or more feet in length, counting and measuring on each cross-section the width of annual rings belonging to each period of its age, say from ten to ten years, and tabulating the changes in height, diameter, form and volume in tables or curves.

To be sure, not only do different species grow at different rates due to their inherent disposition, but each species in itself varies its rate of growth according to climate, soil and light conditions. Hence a classification of the measurements according to "site" classes must be made for each species, and the so-called "yield tables," which record the measurements, are constructed with due regard to the differences of site.

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*Read before the Canadian Institute, January, 1908.

A site in the forester's parlance, then, is the combination of climatic and soil conditions which produce a certain growth energy. In nature there is of course an endless variety of sites, but within a given climatic region a differentiation into five site classes has been usually found sufficient for practical purposes.

Light, next to soil and climate, is a most potent stimulus to assimilation of food materials by the foliage, and hence influences growth. For this assimilation we find that some species require much light, are intolerant of shade, others are satisfied with small amounts, or rather can utilize rays which the first cannot utilize; they can assimilate under the shade of others. There are various degrees of shade endurance possessed by the various species, according to which they can be grouped into light-needing and shade-enduring, and according to whether they have more or less light they grow more or less.

Trees behave very differently as regards growth when growing in the open than when grown in the forest, due largely to difference in light conditions. And, since the forester is interested mainly in the trees as grown in the forest, his measurements are made under forest conditions, and refer to trees in the forest. His deductions may therefore not be applied directly to single lawn trees which are a law unto themselves.

In discussing the laws of tree growth the forester has always in mind a close stand of trees, where crown touches crown, and the whole ground is covered by tree growth. In formulating the laws he must also predicate a pure stand of one species since the mixed stand of many species introduces too many variables.

He constructs, therefore, his yield tables for single species in closed stand, i.e., perfect condition, as a normal standard with which he can compare actual conditions. In such yield tables will be recorded from decade to decade the progress in height, in diameter or in basal area, and the increment in volume on various sites—not only of the average tree but of a whole acre of trees of the same kind.

The object of such yield tables is to enable the forester to relate production to time, and to predict the amount of the harvest if cut at various times, and to choose the most profitable time for such cutting. For maturity of the forest crop is not a natural condition, but an economic condition, which is determined by calculation, either on the basis of maximum volume growth or maximum value increment, or of still more complex *financial* considerations.

The measurements, to be sure, can only be approximations, more or less close; and as seasons vary, and with them the increment, in order to get a clear picture of the lawful progress, it is preferable not to state yearly but only periodic performance, the period chosen being a decade or at best a quinquennium. The annual or *current* increment would then appear really as an average periodic one, the average of ten years; and the *total average* increment would be the amount found at any given period, divided by the number of years up to that period. By plotting the actual findings of many measurements, in a system of co-ordinates representing time and amounts, it is possible to strike an average which in a curve or straight line represents graphically the changes, and from the form of the curve we can get an idea of, and indeed calculate mathematically the rate of progress. A concave trend of the curve, as is well known, represents an increasing, a straight line a steady rate, and a convex form a decreasing rate of progress.

Just as man and other animals exhibit periods or stages of development so we can discern periods of growth in the tree, the infantile and juvenile, the adolescent, the virile and the senile stage, each varying in the rate of growth and character of development.

We note that in the so-called great period of development in tree growth, from the seed to death, at least three or four stages can be recognized during which the rate of growth in all directions varies. From the very slow seedling stage some species pass through a short, others through a longer brush-wood stage, when the tree grows into branches rather than bole. Then usually follows a rapidly increasing rate through the pole-wood stage, when a definite bole is formed, the lower branches are lost, and a definite crown develops, to be succeeded by a steady progress of increment in the young timber stage; finally in old timber the rate retards and nearly comes to cessation. The juvenile period, varying greatly in length for different species, different sites and in different directions of growth, is the one that is least amenable to law; just as among boys the duration of this period of development varies greatly and is very much dependent on outward conditions. But for this period, which withdraws itself from definite mathematical consideration, all species would appear to behave very much alike.

While it is a law of nature that nothing can stand still, but must either grow or die, in one direction, height growth, there is, as we all know, an absolute limit—trees do not grow into the sky; but in diameter and volume there is no cessation of increment until the tree dies. The question as to why trees do not grow into the sky, and why different species have different limits to their height growth is still open for speculation. We dispose of it here simply by referring it to internal disposition, in some degree modified by site conditions, for the maximum height which the same species attains varies with soil and climate. Some species, like the white birches and aspen, attain their maximum height early, but most of our timber trees reach it in 100 to 150 years. The tallest, such as the big trees of California and the eucalyptus of New Zealand with 300 to 350 feet, perhaps take a longer time to accomplish this height.

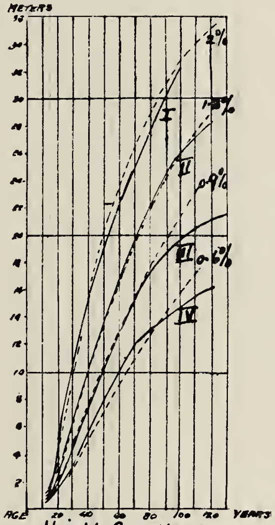
Merely to suggest a physical explanation of the limit to height growth we can imagine that gravity and friction, variable in different species, increase with the growing height for the transpiration current of water which is needed for carrying on life functions, until in drouthy years the supply of water cannot be secured by the leaves and buds and shoots at the tip fast enough, and they die back, to be replaced again and again by new shoots, but unable to overcome the limit set. According to well-known mechanical laws the lifted load of water must be inversely proportional to the heights to which it is elevated; hence in the same proportion as the lifting force decreases through friction and gravity, the annual increments must decrease; that is to say, the higher the tree, the slower its annual height increment. And, reasoning back from an observed or experimentally found maximum height, under the assumption that the lifting force remains the same, and that we have a measure of the initial force, we can construct the formula which expresses the curve of the gradual decrease in the rate and the height at any age (a)

$$h_a = h_{max}\left(1 - \frac{1}{1.0p^x}\right)$$

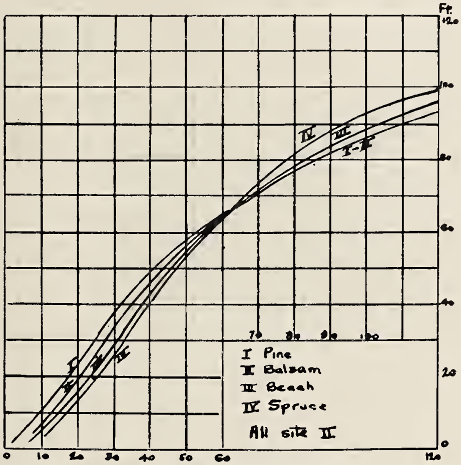
If we know, therefore, that a species attains a maximum height of 35 *m*; that the growing power of the site p is 2 per cent., we know that the height at 60 years would be $35\ (1 - \frac{1}{1.02^{60}} =$ $35 \times .69522 = 24.3327$ *m*.

By actual measurements this formula or law of height growth has been found correct after the juvenile stage is passed. During this latter stage gravity plays a small role and internal disposition even more than external physical conditions, etc., has much influence; the rate during this period is very variable in different species, but follows mostly a compound interest series, i.e. an increasing rate. Some species like the beech and fir start very slowly into the arborescent form with a definite leader; they remain for a number of years shrub-like with bushy crowns, while others, like the aspen and elm, start at once with a rapid height growth, lacking entirely or almost the slow youthful period. It is this difference in the young stage that makes us talk of rapid and slow growers. But the forester who contemplates the future more than the present has learned that the law of the lever rules the world here too, and what is done quickly is usually not done persistently. As a rule the light-needing species are the quick growing in the early stages, but usually they are not persistent, and many, like the aspen and locust, remain small trees.

The tolerant or shade-enduring are mostly the slow but also persistent growers. With these the juvenile period may last 10 to 25 or even 30 years, while the light-needing rarely exceed 5 years before they begin to increase in height under the law of gravity and friction as elucidated. We find then generally a slow progress followed by a rapid increase in rate to a maximum which we may designate as the adolescent stage, and then the longer period of slowly decreasing growth and finally relative stability, which in the curve would be expressed by a horizontal or rather a wavy line of small extension.



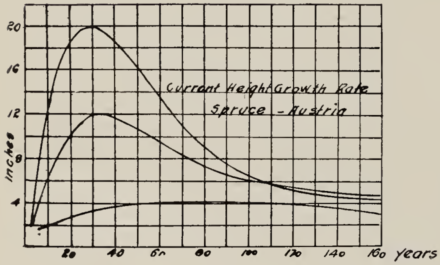
Height Growth
Spruce—S-Germany

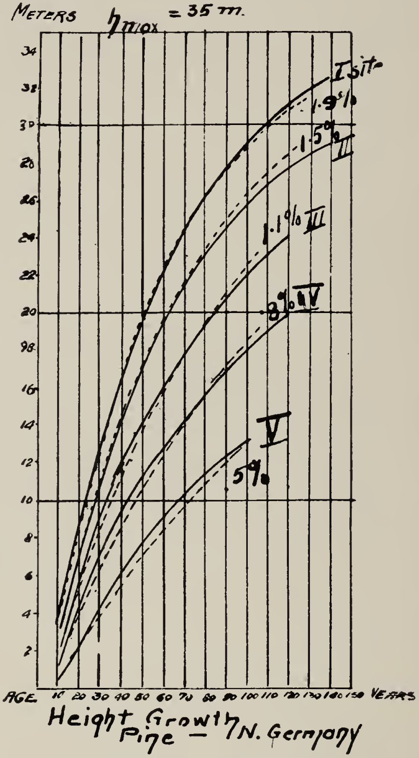


Comparison of Height Growth

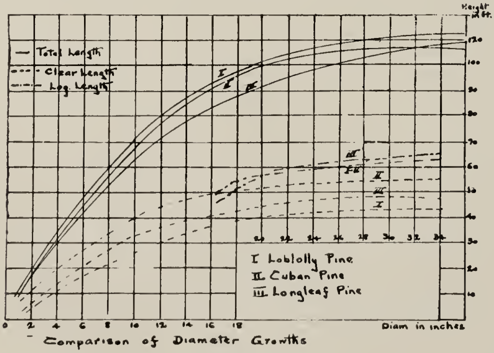
After the juvenile adolescent period is passed a remarkable uniformity of height growth among different species is, in most cases, noticeable, so that if the curves were shifted in such a manner as to exclude the time of the juvenile period, they would nearly cover each other. On good sites the rate p in the formula lies near 2 per cent. up to 2.5 and 3 per cent., while on poor sites it sinks below 1 per cent. It will be clear that the maximum annual or current increment lies somewhere at the beginning of the curve after the juvenile period. With light-needing species this occurs as a rule before the 20th or 25th year, with the shade-enduring species between the 30th and 40th year.

In discussing *diameter growth* the first question is where to measure it. The rule is to refer to the diameter at breast high —*d b h*—say 4 1-2 feet from the base, partly because of the convenient access to this point, partly because below this point (and in very old trees even above this point) there are found root swellings which, if measured in, would give an erroneous picture of facts. By locating the measurement at this height, we exclude at once in most cases the juvenile period from consideration, the time when the tree has still more or less shrub form, and even in the dense forest is more or less branched to its base;

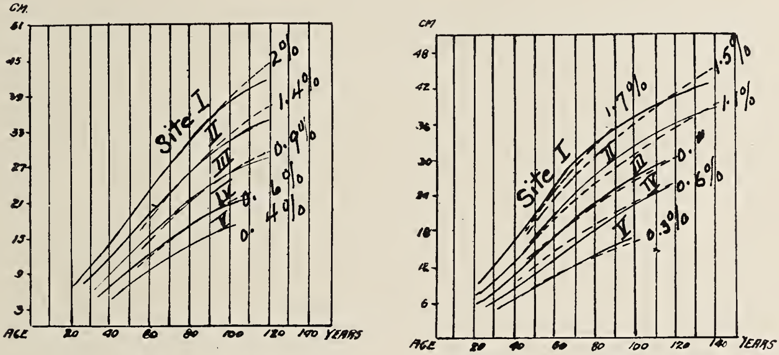




the time when the tree is growing into crown rather than into bole, and it is the bole alone that interests the forester. While



during this early period the tree is putting vigor into height growth and branches, the diameter increase is very slow and its measurement of little practical value. The duration of this juvenile stage, i.e. until the breast height diameter has reached say 6 inches and the bole up to that point and somewhat above is clear of branches, may last 15 to 20 years with light-needing, and 30 to 40 years with shade-enduring or slow-growing species. After this period of slow diameter growth the increment progresses for a long time at a rate which corresponds to the square root of a constantly rising multiple series of the form $d = \sqrt{\frac{4px}{\pi}}$ in which x, the factor time, represents age diminished by the juvenile period, $(a\text{-}i)$, and p is the experimentally found growth vigor of the site. The culmination of the diameter increment rate with most timber trees occurs between the 40 and 60 year on good sites, and some 10 to 20 years later on poor sites. The value of p on best sites lies between 1.5 and 2 per cent. with regular decreasing progression from the higher to the lower site classes.



Spruce . N. Germany Pine N. Germany.

DIAMETER INCREMENT

AVERAGE TREE

Incidentally I may mention that to determine the rate of growth at which a tree is growing, all that is necessary is to secure a core or chip showing the growth of the last 10 or 20 years, when by the use of the formula $p = \frac{400}{nd}$ in which d is the diameter, n the number of years which it took to make one inch, the probable rate for the next 10 or 20 years may be determined.

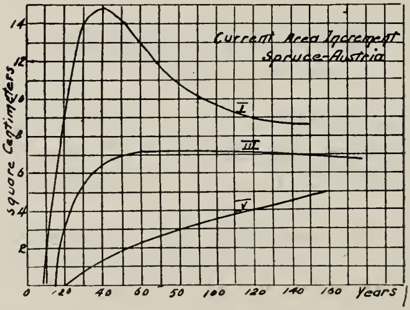
A quick mathematician will at once see that the formula for the diameter growth is derived from the more obvious one $\frac{1}{4}\pi d^2 = p\,.x$, which expresses the relations of the basal area as a direct function of time.

To the forester who is concerned with volume production the area increase of the tree is more directly of interest than the diameter, although to be sure, he has to measure the latter in order to secure an insight into the area increment. That the area does not grow in the same proportion as the diameter but as the square of the radius every mathematician knows. Hence the width of the annual ring may be decreasing, yet, being laid on over a larger periphery, the narrower ring may represent a larger area; in other words, neither the diameter increments nor the width of annual rings give directly an insight into area or volume increments.

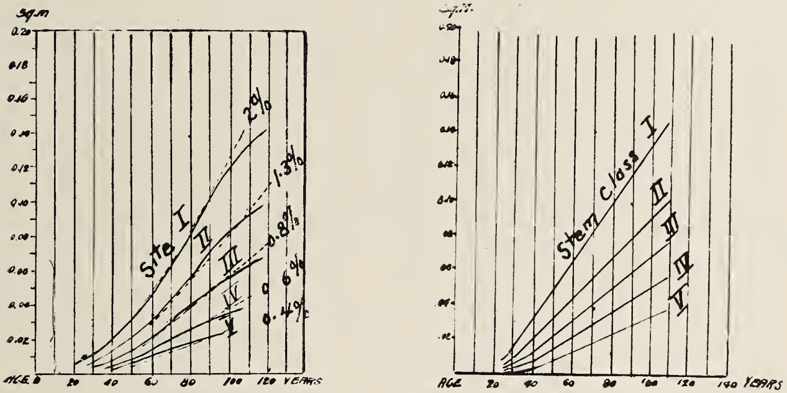
No other measurement expresses so completely the growth conditions of the tree as that of the cross-section or basal area; from it the life history of the tree can be most readily read.

Examining the cross-sections of various trees, we may find this one showing a fair ring width in the centre, which later rapidly declined; this attests that it was once among the dominant, but gradually fell into the sub-dominant. Another shows by the narrow rings in the centre that it started life with small chances, but the sudden change in the rate of growth tells us that an overshadowing neighbor or branch was broken or removed, changing the conditions of growth. Others again show by their fair and even progress that they grew up in close position, which permitted only slow but constant increment.

While in the forest the trees which are more or less deprived of light by neighbors, show naturally great variations in their area growth, and usually with age a rapid decline; the dominant trees or the main stand, in full enjoyment of light, show a most remarkable regularity in area increment from period to period, which, unlike the height and diameter growth, follows a simple multiple series of the form $A = p\ x$, i.e. the area is a simple function of time, the curve becomes a straight line; in other words the basal area increases after the juvenile period in the manner of a simple (not compound) interest series with the rate *p*. The value of *p*, the growth energy, varies in the forest not only with species and site, but is especially influenced by difference in light conditions which differently placed individuals enjoy. It is customary to classify trees from this point of view into five classes: the predominant and codominant having their



crowns free and not overshadowed by neighbors, the subdominant having their crowns already narrowed in, being in danger of falling into the dominated classes of oppressed and suppressed which are doomed to death by the shading influence of their neighbors. The values of p for dominant trees lie between 1 per cent. and 4 per cent., while the lower stem classes range below 1 per cent. E.g., in a spruce forest the growth energy of the different tree classes varies nearly as 1 : 2 : 3 : 6, from the suppressed to the predominant, because the first have only poorly developed crowns with few leaves in poor light, while the last have an abundance of foliage in full enjoyment of light and hence grow six times as fast. In other words, the basal area grows in proportion to the active foliage area. The maximum of the area increment occurs in trees grown in the open mostly long after the 100th year, in the dominant trees of the forest usually between the 50th and 80th year, but on poor sites much later.



SPRUCE N GERMANY

SPRUCE SITE II SAXONY

BASAL ACRE INCREMENT
AVERAGE TREE

An interesting biological explanation of the difference in behavior of different species as regards the absolute amount of basal area increase is found in the consideration that on a given acre with given growth conditions, with the same amount of sunshine and water, all species will produce the same amount in *weight* of vegetable substance. Hence, species with high specific weight, the hard heavy woods, must show smaller annual rings and area growth than the light soft woods, which for the same weight must deposit larger volumes of wood.

Before looking into the mathematics of volume growth, it is necessary to have some idea of the *form* or shape of the bole of trees, which means an insight into the diameter or area growth *at varying heights* outside the breast-high point of measurement.

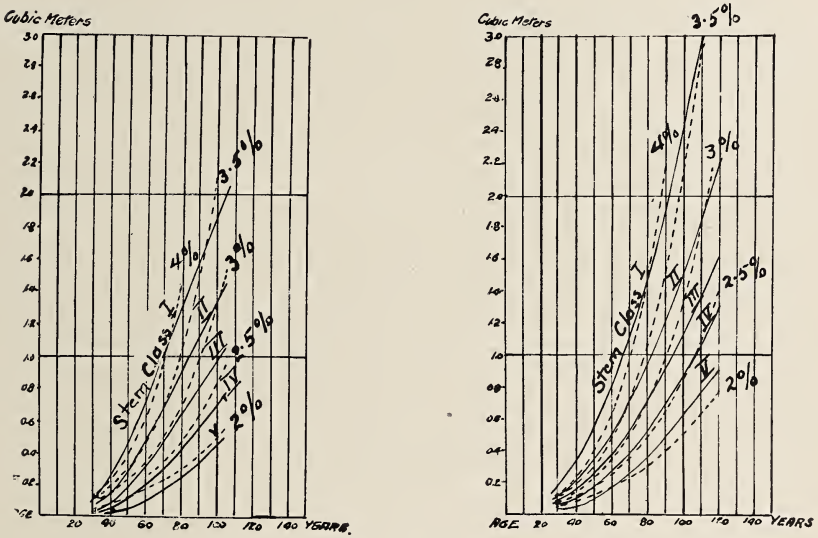
The form of a tree bole is neither a cylinder nor a cone, but it *tapers* unevenly and lies between the two, a paraboloid or neiloid, with variations which are mainly due and depend upon the character or amount of crown. The tree in the open, branched to the base, develops a form almost conical, the width of the same annual ring increases from top to base and so does the diameter in proportion, since each additional branch adds to the food supply. A tree with a small crown cannot elaborate food materials enough to make even a uniform envelope all the way down, the ring width and the area decrease from below the crown downward, and the result is a cylindrical trunk. The older the tree, even in the open, the more does this proportion of crown to circumference decline, and the more cylindrical does the form of the bole grow. In very old and poorly fed trees, the deposit of wood may fail altogether in the lower portion and the annual ring is not developed. In the crown the same conditions, an increase of ring width and area downward occurs, because each additional branch adds food supply, and hence the top becomes conical. Within these two extremes of nearly conical and nearly cylindrical bole, a number of other forms are found according to size and character of crown and species. By a large number of measurements so-called *form factors* have been established by which for different species, different sites, different age, and different phases of development, the variation from a cylinder is expressed, so that the volume of a tree is expressed by the formula $vol. = a.\ h.\ f.$

The values of f lie usually between .4 and .6, i.e., the volume of the bole of a forest grown tree is about one-half the volume of a cylinder with the basal area at breast height and the total height of the tree.

There have lately been other interesting mathematical relations worked out between the diameters at varying heights, which we cannot stop to discuss.

The *volume* increment is finally the most important, and naturally exhibits the resultant of all other directions of growth. Here the periodic stages of development or changes of rates are more evident than in all other directions of growth. During the juvenile stage the tree is concerned in developing its root system and the assimilating organs; there is little volume growth of the stem, so little indeed that it cannot be shown in the curves for the first two decades or more. The length of this slow juvenile period varies, as in all other directions, with the species, with the site, and with the density of the forest. The shade enduring species, as a rule, extend this slow period longer than the light-needing. A close stand, where the individual is curtailed in its opportunity for expansion, has the tendency to lengthen the slow period, a good site where trees are best fed, to shorten it, while open stand and poor site have the opposite effects. A most important deduction may be made at once from the realization of this slow period, namely that with shade-enduring species and on poor sites the rotation, that is the harvest time, must be longer deferred, else we repeat the slow period too often and the total production is curtailed merely by this repetition of the slow period.

After the 10th to 25th year when the trees are well established (and on poor sites much later), the volume increment starts on a rapid and constantly increasing rate as the concave curves show, namely at a compound interest rate of the form of an exponential series $y = 1.\ op^x - 1$. Such a rate continues often for many decades and even a century or more, on the poorer sites, the white pine being perhaps the best exponent of the persistent growers. Here, too, we can again observe the law of the lever: The greater the p, i.e. the more favorable the growth conditions of the site, the sooner comes the decline to a lower rate, until the compound interest may fall to a simple interest series; the curve becomes a straight line. On the other hand when the initial rate is slow, it remains constant the longer. The maximum of the annual rate lies towards the end of this ascending period and does not consist in a single culminating year but remains for several years constant before the declining rate begins, i.e. before compound interest rate changes to simple



SPRUCE-II SITE-SAXONY SPRUCE-I-SITE-SAXONY

VOLUMNE INCREMENT

interest rate. This with many species takes place so late in life that the inquiry loses its economic value: the trees are harvested before that time, for value increment per unit ceases to grow before volume increment declines. All other things being equal, the amount of light at the disposal of different individuals makes the greatest difference in their increment and hence the density of the stand, the number of trees on an acre, influences the absolute amounts of wood deposited on the different individuals.

While, therefore, for dominant trees the value of p lies between 2.5 and 6 per cent., the third class stems would be reduced to 1.8 to 4 per cent., and the lowest class remains somewhere below 2 per cent. The rates of volume growth for the five stem classes, from the lowest to the dominant, progress as 4, 5, 6, 7, 8, that is to say, the best placed trees will grow twice as fast as the poorest placed, and sometimes the difference is even greater. But, while the rate in the dominant reaches its culmination early and then declines, the low rate of the slower growing tree may continue for a much longer time at even progress.

Similar differences of behavior are found with trees of the same species on different sites. For example, the Norway Spruce on best sites shows culmination of the rate of volume growth between the 60 and 80 years with 8 cubic feet, then declining slowly. But the poorer sites have not reached the end of the increase in rate in the 160 year, and often continue to increase beyond the 300 and 350 year, although, of course, the actual rate remains much lower during the whole life than on the good site.

It appears then, that in all directions, in height, diameter, and volume increase the greatest growth energy is developed on good sites in the younger years or middle life, with a subsequent decline, while on the poorer sites the growth energy is slow but steady for a longer time.

By proper management of the light conditions the forester has it in his power to influence the rate of growth and to make even slow growing species produce more per acre than they naturally would. To give a concrete example of how this volume increment progresses, we may refer to the Scotch Pine, probably closely resembling the Red or Norway Pine which from 10th to 80th year grows on best sites at the rate of 3.5 per cent.; from the 80th to 110th at 3 per cent., but on third class sites, which are its common heritage, the rate is only 2.5 and 2.3 per cent. respectively.

ACRE INCREMENT.

The forester is, after all, only incidentally interested in the single tree, he deals with acres of trees, and while the single component has, perhaps more economic importance to him than the single blade of wheat to the farmer, the acre production must finally be his main interest.

Lawless as the mixed forest appears to the layman, the biologist knows how to account for the existence of each component, and can analyze the laws under which the composition has come about, and how it progresses in development. Hopeless as the task may appear, the forester has learned to measure the amount of progress, how much the performance from period to period has been and is likely to be under similar conditions.

If it is necessary to classify carefully and generalize broadly in defining the law of progress of single individuals, the classification must be still more circumspect where so many variables are possible, and the generalizations must be drawn still broader with acres. The first broad generalization which a mere biological consideration will lead us to, and which measurements have proved to be correct is this: that an acre of given quality will produce, with given sunshine and rain, the same amount of dry weight of vegetable matter without regard to the species employed. This vegetable matter, to be sure, may consist of roots, stems, branches, leaves and fruit in varying proportions, and in volume, especially the useful volume, the differences may be very great according to the looser or denser structure or the varying specific weight of the plants. But if the consideration is confined to the economically valuable woodgrowth above ground, it may be stated that timber trees which form stands produce approximately the same amount of wood in dry weight, namely annually between 2,700 and 3,600 lbs. per acre on first class sites, down to 1,350 lbs. on poorest sites. Knowing the specific weight of the different species we can then arrive at the volume production by multiplying the weight per acre with the specific weight of the wood of the species, and may learn that one species e. g. White Pine, may produce from the same acre 3 to 5 times the volume which another species e. g. the heavy beech, is capable of producing.

It is also of interest to note that although great changes in the number of trees per acre occur, the *annual* product of wood in weight inclusive of bark continues constant for a long time until high age, with only small variations.

The important deduction is to be made from this that not the number of individuals, but the closeness of the crown cover, i.e., the amount of foliage at work, will decide the volume product per acre, hence that the increment can by thinning be transferred from one tree class to another, if this is capable of growing into the space opened up to it.

In a given case the number per acre had been reduced in 100 years from 16,000 to 112, thinning out and removing from time to time very considerable quantities of wood, without decreasing the average of total weight increment per acre from decade to decade.

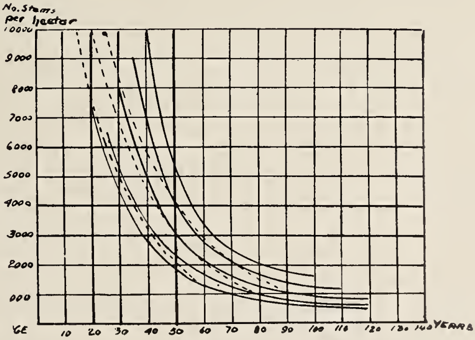
The specific weight of wood itself really decreases with age, that is to say, young wood is heavier than old, so that this compensates for the small volume production in the juvenile and the increasing rate in the long virile period: the volumes are inversely proportional to the specific weights: $V_1 : V_2 = \frac{1}{S_1}\ \frac{1}{S_2}$ This holds not only from species to species, but from individual to individual.

There are three considerations always present in the forester's mind when he discusses density of his crop, i. e., tree numbers per acre. A dense stand produces branchless boles, a desirable form: it also makes a close crown cover, shades the ground, an essential factor in keeping soil conditions favorable. On the other hand, with many trees to the acre the wood production is distributed over so many individuals that each secures but little, even the best grow only slowly in size, and size is an important quality for the use in the arts, hence the problem is how far to follow each of the three aims, of form, of soil cover and of volume increment to be deposited on as few individuals as will suffice to satisfy the first two objects.

It is evident that the question of numbers is of utmost importance. In the dense sowing of nature a quarter million plants may start together on an acre, but in the first years the infantile death rate, due to lack of vitality and unfortunate domestic conditions, as in the human world, is great, and probably not over 100,000 live through the first year. Then, as these expand with their roots into the ground and with their foliage into the air space, there comes competition for space, for water, for food materials, for light—a struggle for existence. Some more favorably placed or of more rapid height growth overtop others, and by and by a differentiation into tree classes is discernable, such as we have alluded to: there are developed masters or dominant, and subordinates or dominated. The latter are gradually crowded out of the race for lack of light, or water, and are suppressed and finally die. Just as in the single tree, of the many buds which are set only a small percentage can develop, so on the acre there is with the expansion of the single individuals a reduction of space and this can be met only by reduction of numbers. This reduction, whenever the stand is a close one proceeds from year to year or from decade to decade at a certain rate, which, like all performances in nature, varying of course with species, sites and age, can be nevertheless demonstrated as subject to certain laws. It is clear that this decimation must proceed in inverse proportion to growth, and hence to the shading value of the dominant class, and that means mainly in proportion to height growth, so that a curve for the decimation in numbers, or death rate, would appear as the negative picture of a height curve.

After the juvenile period, which may last from 5 to 35 or even 50 years, and when the average standing room per tree has become about 10 square feet, or when say 4,000 trees occupy the acre, and the rapid height growth begins, the struggle becomes fiercest. As long as the height growth is rapid and inrceases, as we have seen, at a compound interest series the numbers must also decrease as rapidly in a reciprocal or discount series of the form $\frac{1}{1.op^x}$, or by introducing the acre figure $\frac{43560}{1.op^x}$ will be the number at any time for this period; x being the factor time or age minus juvenile period. Then, when the rapid height growth period is passed the decimation slows down to a simple discount series of the form $\frac{1}{p^x}$. And, when the height growth is nearly finished and the number has sunk to about 400, the rate is further reduced to $\frac{1}{1.op^{\frac{x}{2}}}$. Finally, when about two hundred trees occupy the ground they can peacefully live together without interference, and only accidents diminish their number, so that only 1-10 to 1-50 of the trees that started to grow will be found at harvest time on the same acre.

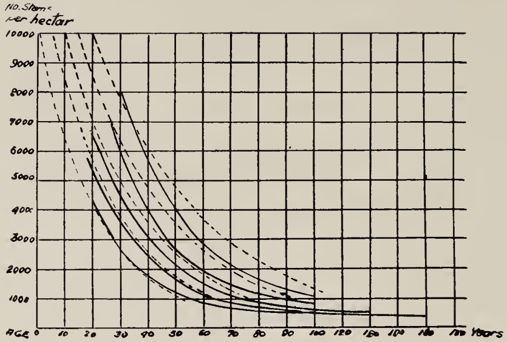
On good soils and with rapid growers, when dominance is early developed, the numbers fall more rapidly than under opposite conditions. In other words, there are more individuals at a given age to be found on poor sites than on good, and the difference in development of single individuals of the different tree classes is not so pronounced as on good sites. The values of p vary from 7 per cent. to 8 per cent. for spruce and fir on best sites, down to 3 or 2.5 per cent. for pine on poorest sites.



Spruce N. Germany

NUMBER DECREASE PER HECTAR

As stated before, the forester interferes with the natural progress of decimation by thinnings. Having first secured by dense position a branchless bole of sufficient height he secures a more favorable distribution of growth on fewer individuals, thereby hastening the development of the fewer select or *elite* to serviceable size.

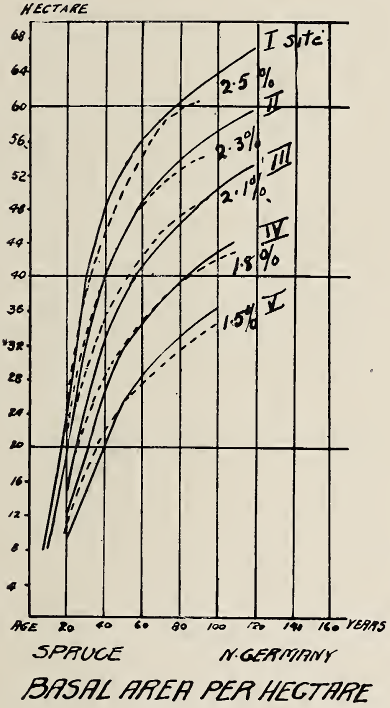


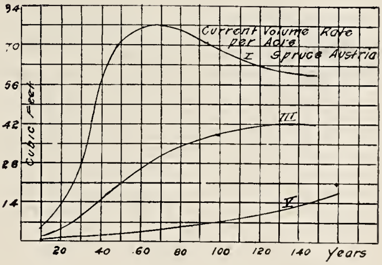
Number Decrease per hectar
Pine S. Germany.

Now, to secure a conception of how the volume production of a whole stand per acre progresses we must first inquire into the factors which produce the volume, namely the basal area of all the trees and their average height and form. We can imagine the basal or cross-section areas of all the trees combined or summed up into one area, the basal area of the stand, and consider the changes which this total area undergoes through the life of the stand. There is an increase in the basal area of each component and hence of the total or sum of all, but there is also a dropping out of individuals and this influences the rate at which the total basal area of the acre progresses from decade to decade. Instead of using the sum total, we may divide it at once by the number of trees involved in each period, and thus secure the progress of the average basal area or the area of the average tree.

During the juvenile period the competition is not keen, and often young stands start without their full complement of plants, the stand is open, and no lawful number decrease takes place. Only when the crown cover is closed, does the competition begin and the two factors of individual increase and of number decrease enter into the problem. This juvenile stage as a rule does not last as long as when the single individual is only concerned. With rapidly growing trees 5 to 10 years, with slower growing 10 to 15 years and rarely more, brings the stand into a well-defined law of progress. It is evident that if we combine the formula of number decrease and of the average tree increase into one expression we must get the basal area increment for the whole stand.

Such a combination brings us, indeed, to the experimentally established formula of the curve, which during the period of rapid decimation reads $2\ A = \frac{px}{1.op^x}$. In other words both this theoretical development and the actual measurements show that the higher the growth energy of a stand, the more rapidly, to be sure, increases the area of the single stem, but also the more rapidly sinks the stem number, the former following a multiple series of the squares of p, the latter following the reciprocal of an exponential series with the basis $1.op$, and the two items stand in the relation as expressed in the formula.



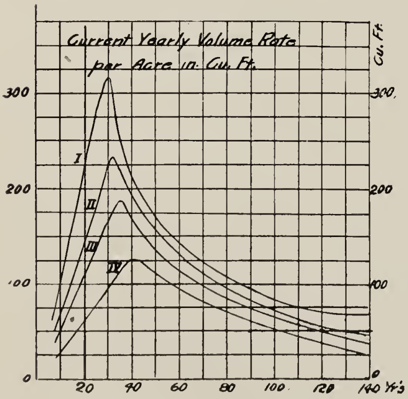


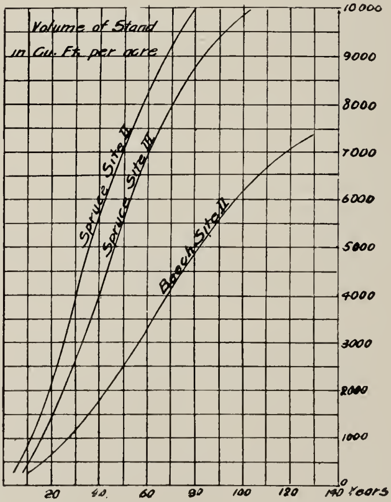
The culmination of this series is reached when the death rate changes, and of course the sooner the greater the growth energy; the higher the p. Then follows a period, during which the basal area grows still constantly but the numbers decrease more slowly, requiring twice the time for the same amount of reduction, the denominator of the formula becoming $1.op^{\frac{x}{2}}$, that is to say, the curve becomes shallower. For different species and sites the values of p vary between 1 and 2.8 per cent., the shade enduring conifers and the best sites making the best progress.

Finally we come to the volume increment per acre, the ultimate object of the forester's work. The volume per acre is of course the product of the number of trees and the volume of the average tree, or from what has been shown before for these two factors, the increment is expressed by a combination of the two series of the form $\frac{1}{1.op^x}$ and $1.op^x - 1$, that is, $vol_x = 1 - \frac{1}{1.op^x}$ This expression we find is analogous to the one found for the height curve of the single tree, and so we come to the realization that there must exist proportionately between the progress of height growth of the average tree and the volume increment of a stand. This interesting fact of the analogy of height growth and volume growth of closed stands explains itself readily by the consideration that the number decrease is a consequence of the height growth of the dominant stem classes which suppress their weaker brethren. Both, decrease of height growth and decrease of numbers progress according to the same reciprocal series, namely $1 - \frac{1}{1.op^x}$ and have therefore the same compensating influence on the increment, which would otherwise progress according to the compound interest series $1.op^x - 1$.

In other words, the limit which the soil area sets to expansion has the same mathematical influence on the total volume increment, as the influence of gravity has on height increment. Or, again, the increment of the average tree is inversely proportional to the number diminution, since with increased p the volume of the single tree grows faster, but also the number of

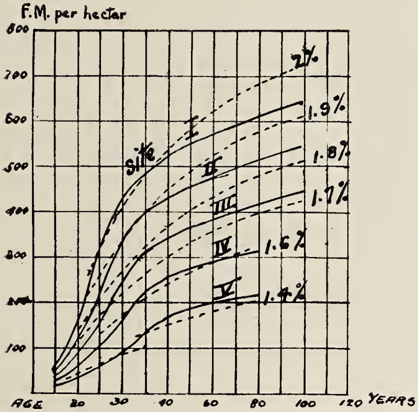
Fir in Baden



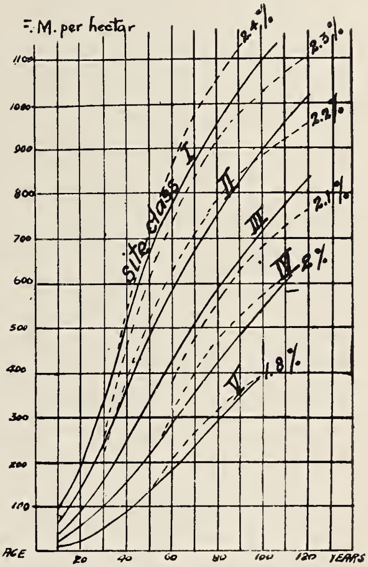


trees decreases faster. To the experienced forester the height growth becomes therefore the best measure of the site quality. Especially the depth of the soil finds very striking expression in the character of height growth and crown development.

It is characteristic of the current volume increment rate per acre that on the better sites a very decided culmination of the rate occurs the earlier the greater the growth energy, and that to the rapid increase in rate of the time before the culmination corresponds an equally rapid decline after it. In spruce the culmination may occur on best sites around the 50 year with say 250 cubic feet per acre, in medium sites some 15 years later with only 115 cubic feet, and on poor sites with less than 50 feet after the 100 year.



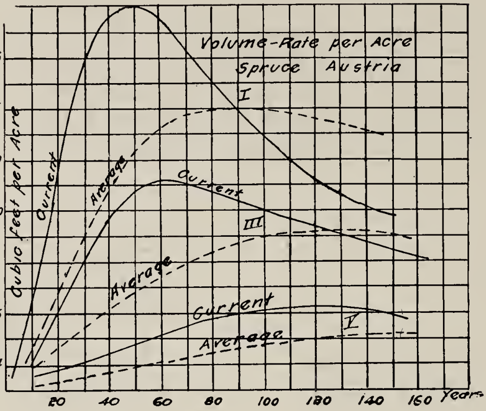
Volume Increment per hectar
Pine Saxony.

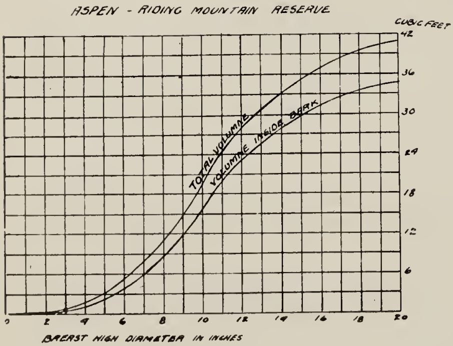


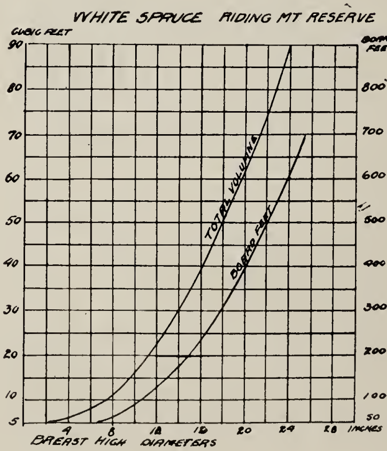
Volume Increment per hectar
Spruce S. Germany.

On the whole the progress of volume development of stands proceeds more slowly than that of single trees, the stem number furnishing the moderating influence.

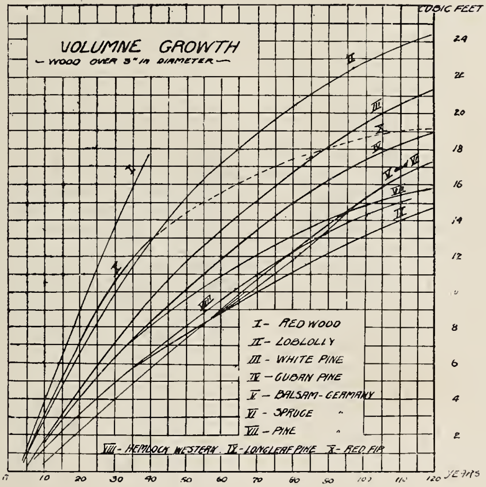
One of the important questions which the forest manager asks is, not when the highest rate of growth occurs, but when is the maximum production per unit of time attained; when is the highest *average* increment reached? It is evident that this has occurred when $\frac{vol.}{time} = maximum$, and it can be mathematically proved by differential calculus or by mere logical consideration that this occurs when the average increment is equal to the current increment. Contrary to former beliefs, this time of maximum volume production occurs rather earlier than was supposed, usually with light-needing species, which have a short juvenile period and rapid development, before the 40 year, with shade-enduring before the 80 to 90 year, on better sites earlier than on unfavorable ones. Since at those ages most trees are still too small for advantageous use, it cannot be the aim of the forester to grow the largest amount of wood per acre, but in order to determine the proper harvest time, the further modification of quality and value increment must be made, which can also be determined by mathematical methods.







There is only time left to present a few striking deductions from the yield tables. So lawfully does a stand of white pine develop, if naturally grown, that when its height growth is practically finished we can determine its contents by measuring merely the three stoutest and seven of the slimmest trees, and dividing by ten when we have the volume of the average tree which multiplied by the number of trees making up the stand, gives us the volume of the stand. Again, by measuring the diameter of all the trees and ranging them in sequence by size from the stoutest to the slimmest the average tree will be found at 40 per cent. from the stoutest. We can also feel certain that in a pine forest grown naturally, if the trees be arranged according to diameter classes, 40 per cent. of the total volume of the stand is represented by the first 20 per cent. of trees; 24 per cent. by the second 20 per cent., 17 per cent. by the third, 12 per cent. by the fourth and 7 per cent. by the last 20 per cent. In other words, the stoutest half of the number of trees represents more than two-thirds to three-fourths of the whole volume.



I hope to have impressed you with a realization that even the least promising conditions of nature can be reduced to mathematical expressions and can be proved to be the result of lawful procedure. Some time, we hope, instead of relying on European species and conditions to prove these laws as applicable to our own species and conditions, when we shall find that nature works on the same lines on this continent as in the Old World, and that, whatever difference in economic conditions may exist, the silviculture of Europe is applicable here.

REINFORCED CONCRETE COLUMNS

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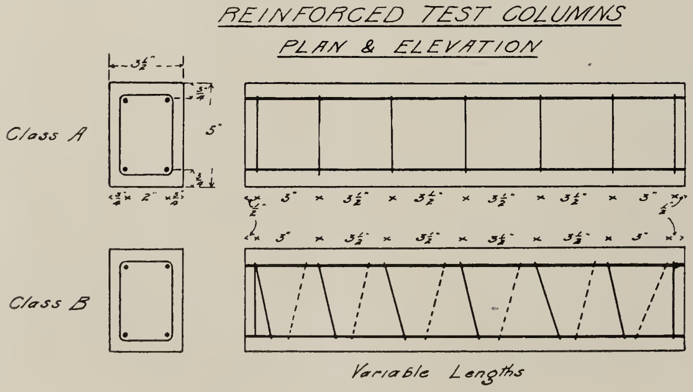
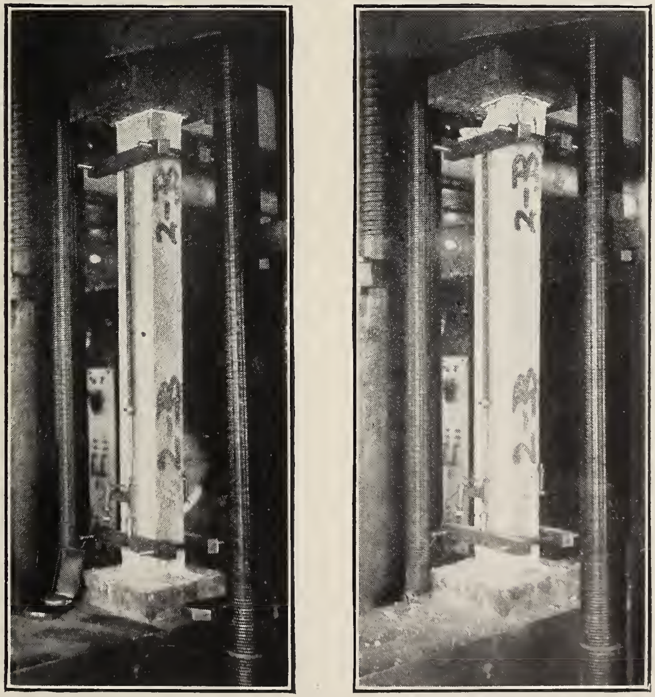
Perhaps no subject in the engineering world has excited more interest or comment within recent years than that of reinforced concrete. Its comparative cheapness, its adaptability to so many varieties of construction and the general satisfaction which it has given when the design has been careful and the work reliable, have given it ever increasing popularity. The intention of this article is to discuss briefly in the light of some recent experiments, the subject of reinforced concrete columns, these experiments having been conducted in the testing laboratory of the Department of Engineering. We are indebted to a large extent for these results to the Roman Stone Company of Toronto and to Mr. G. B. Ashcroft, its former superintendent, through whose kindness the columns in question were made and presented to the Department. With the outlook for better facilities in the near future, in the department of Applied Mechanics, it is the intention to pursue carefully the study of this and allied problems.

These reinforced columns were of two varieties: Class A, in which the upright reinforcement consisted of four 3-8″ round steel rods placed as shown in the sketch with an additional rectangular hooping of 3-16″ steel rods; Class B, in which the upright reinforcement was similar to that of Class A but where a spiral form of 3-16″ reinforcement replaced the rectangular form of the other series. The following table gives the dimensions of the various columns tested:



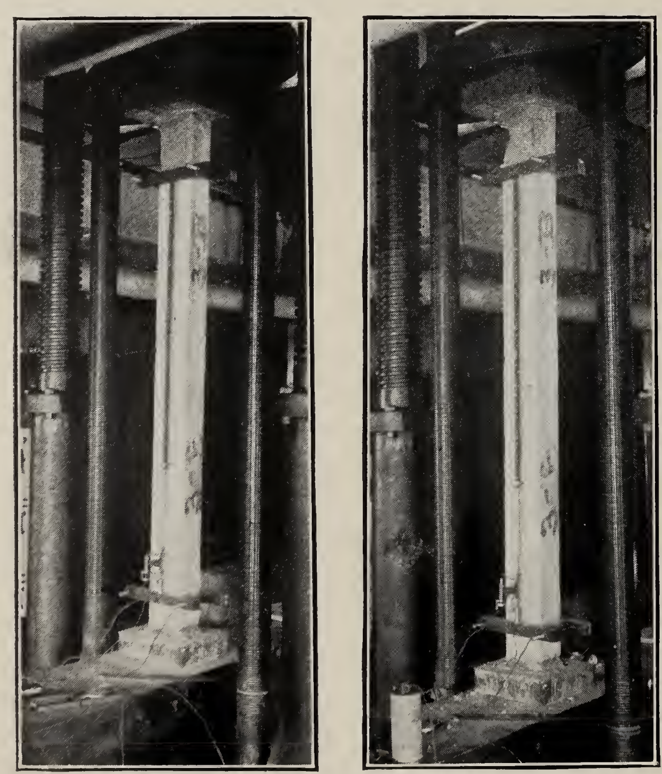
Reinforced columns:
Column 1-B, 3½"x5"x21" in length.
Columns 2-A and 2-B, 3½"x5"x42" in length.
Column 3-B, 3½"x5"x63" in length.
Column 4-A, 3½"x5"x84" in length.
Non-Reinforced columns:
Column No. 1, 3½"x5"x20" in length.
Column No. 2, 3½"x5"x23" in length.

The columns were tested in the 100-ton Riehle' machine of the testing laboratory; they were set carefully in place so as to be truly plumb and each end was well cushioned against the cast iron heads of the machine by the use of mortar. A mortar of neat cement was found to be most satisfactory provided the columns were allowed to stand over night before testing, in order to give time for the setting of the cement. Plaster of paris was used as cushioning mortar in the testing of columns 2-B and 4-A but its rapidity in setting made it difficult to handle and did not permit of an even setting of the ends of the columns. It was also noted that the ultimate load borne by these two columns was considerably below the average.



Column 2B Before and After Crushing

The deformations due to loading were measured by means of the apparatus attached to the columns as shown in the half-tones. This apparatus consisted firstly of two collars attached to the column not far from its upper and lower extremities. To the upper collar and on opposite sides of it were made fast two telescopic rods which could be adjusted for a varied length of specimen. A pair of micrometer screws obtained from a dismantled Reihle′ compressometer were rigidly attached to the lower collars and on the movable arms of these were made to bear the telescopic rods. The loading of the column thus caused the collars to approach each other. These in turn caused the telescopic rods to force down the movable arms of the compressometer. The amount of this motion was registered by means of an electric contact device. The readings were recorded to $\frac{1}{10,000}$ part of an inch, the average of the two compressometer readings being taken to represent the true deformation. The loads were applied at intervals of 2,000 pounds and the compressometer reading noted for each. It will be interesting to note that in



Column 3B Before and After Crushing

each case the column failed in pure compression, no buckling of any kind such as usually accompanies the failure of columns of steel or wood having occurred.

The concrete was of a fine aggregate and was cast in horizontal sand moulds, as is the custom in the manufacture of Roman stone. An examination of the broken specimens failed to show any settlement of the aggregate at the bottom of the moulds so that the columns were quite homogeneous in structure. The concrete was matured in sand for a time and afterwards in air under cover so that practically all moisture was excluded. The average crushing strength, found from a number of tests made on samples of this concrete, was 1720 pds. per sq. in. German Dykerhoff cement was used. It may be of interest to note that the crushing strength of these samples is considerably less than has been found for samples of similar age taken from other runs of stone manufactured by this company and tested in the engineering laboratory.

The reinforcement consisted of mild open-hearth steel, purchased in the open market. All rods were round. The elastic limit was a trifle high but otherwise it was comparable with what is usually sold under that name. A table showing the properties revealed in some six individual tests is given below:

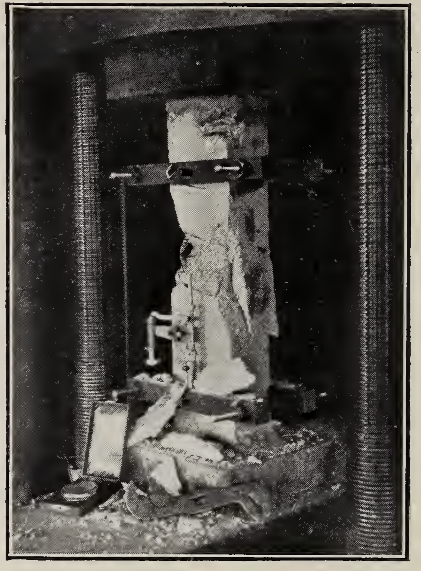
COMMERCIAL TESTS OF STEEL REINFORCEMENT.

Number of Specimen	Elastic Limit Strength (Pds per sq. in.)	Ultimate Strength (Pds per sq. in.)	% Elongation in 8 ins.	% Contrac. in Area.
1	43,100	66,600	25	57
2	41,900	64,800	26	59
3	43,000	64,600	25	56
4	43,100	67,400	27	55
5	43,100	67,600	27	53
6	42,900	67,500	26	54
Average	42,800	66,400	26	56

Figures 1, 2, 3, 4, 5, 6 and 7 are the stress-strain diagrams for the seven different columns described above. The ordinates represent stress, that is, the quotient of the total load on the column divided by the total area of the cross-section; and the abscissae represent the strains or the deformation per unit of length intercepted between the collars of the compressometer device. The absence of a constant ratio between stress and strain is apparent in every case, the curves deflecting downward in most cases almost from the start. This is in general agreement with what is frequently called the parabolic stress-strain relation and is in accord with the findings of all experimenters in plain and reinforced concrete.

In order to find what portion of any stress was carried by the concrete and what portion by the steel, a method adopted by Talbot was employed. It was assumed that the steel and the concrete deformed together. If the elastic limit of the steel be not exceeded, the stress therein will be proportional to the strain.

For a strain of .0014 say, the stress in the steel, taking E_s, Young's Modulus, to be 30,000,000, would be $f = .0014 \times 30{,}000{,}000 = 42{,}000$ pds. per sq. in. This, it will be observed, is a stress slightly below the average elastic limit of the steel as given in the table of results of tests thereon. Let A denote the total area of the column cross-section and p the ratio between the steel and the concrete. Then the total load carried by the steel, corresponding to the stress assumed, will be $42{,}000\ p\ A$ pds. If this quantity be divided by the total area of the cross-section, A, we have as quotient, the number of pounds per sq. in. *of total area* which the reinforcement carries. The numerical value of this will be $42{,}000\ p = 42{,}000 \times \frac{2\frac{1}{2}}{100} = 1050$ pds. per sq. in. Through a point in the diagram whose co-ordinates are 1050, and .0014, a straight line was drawn to the origin. This will be subsequently referred to as the line for steel. From what has been said, it is apparent that the portion of any ordinate below this line will give the stress in pds. per sq. in., *based on total area of cross-section* which the steel supports. In consequence, therefore, that portion of the total ordinate intercepted between the line for steel drawn as described, and the curve as plotted, will be the stress in the concrete for the corresponding strain. Referring to figure 3, we see that the stress, 1620 pds. per sq. in. corresponds to a strain of .001. The line for steel shows that 750 pds. per sq. in. of this is supported by the reinforcement. From this it follows that the accompanying stress in the concrete

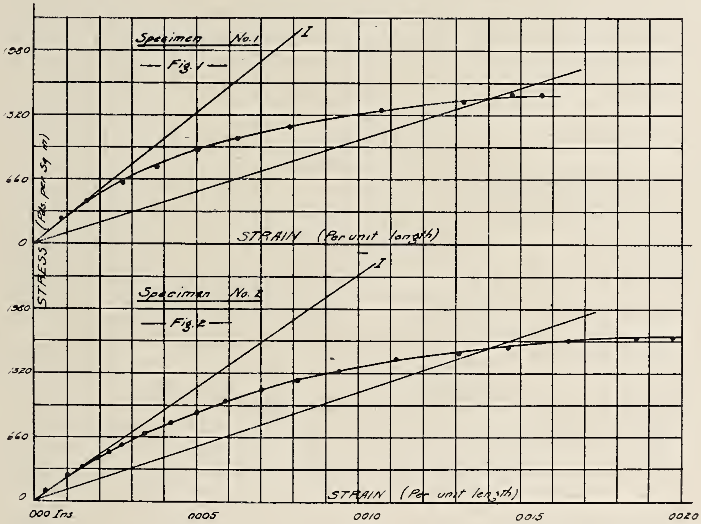


Column 1B Showing Mode of Failure

is the difference or 870 pds. per sq. in. The line for steel has been drawn, it will be noticed, in each case to the ordinate through .0014 as this corresponds to a stress of 42,000 pds. per sq. in., substantially equal to the elastic limit of the steel.

In order to find the maximum stress in the concrete *occurring either prior to or in coincidence with the elastic limit of the steel,* a tangent to the curve parallel to the line for steel was drawn. The point of tangency on the diagrams is denoted in each case by the letter *T*. Singularly enough, this point corresponds in every case very nearly to the elastic strain of the steel, viz., .0014. The values of the simultaneous stresses are given in the subjoined table. The stresses in all cases were scaled from the plot and the tangent was drawn by the usual geometrical method.

PLAIN CONCRETE COLUMS

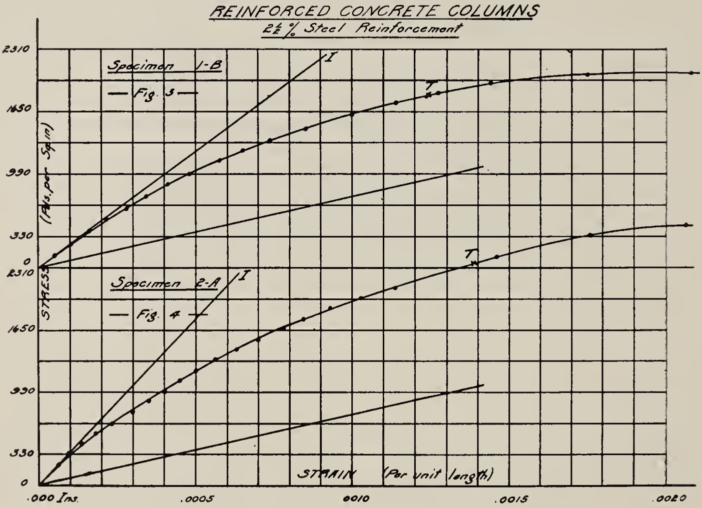


Stresses Corresponding to Point T

Column	Stress in Concrete	Stress in Steel	Strain
1 B	890	37,500	.00125
2 A	1,320	42,000	.00140
3 B	1,650	43,500	.00145
2 B	1,050	33,000	.00110
4 A	1,380	37,500	.00125
Average—	1,260	39,000	.00130

As to the manner of the distribution of the total stress between steel and concrete, after the deformation .0014 is passed, little can be said with certainty. The probability is, however, that the curve for steel flattens quite markedly, producing as will be seen from an examination of any of the graphs submitted, stresses in the concrete greater than those in the above table. This is within the realm of probability, since from the table given, it is seen that the average stress up to or coinciding with the elastic limit is only 1,260 pds. per sq. in. Now the average ultimate compressive strength of the concrete, it will be remembered, was 1,720 pds. per sq. in. so that a margin for increase remains. The rising of the stress-strain curve after the elastic limit of the steel has been passed, is thus capable of an explanation, although an exact analysis of these later stresses is quite impossible. The assumption has been made in this discussion, that the elastic limit in compression is the same as that in tension. The error in this assumption is probably very small.

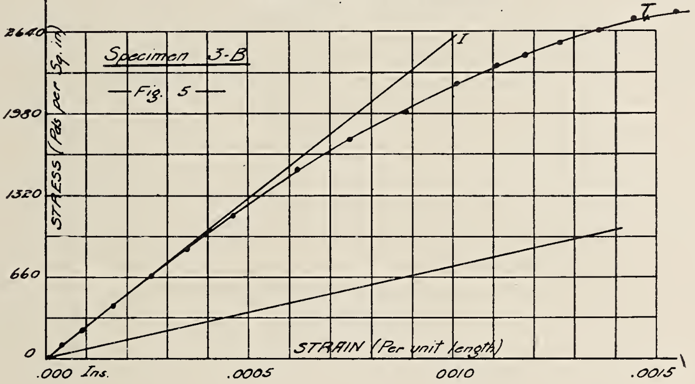
If concrete hardens in air, a shrinkage occurs; if in water, an expansion results. Experiment has shown that a 1:3 plain mortar hardened in air will shrink, in consequence, from 1-20 to 4-20 of one per cent. in its dimensions. Where reinforcement is used, the deformations due to this cause are much less, but notwithstanding their smaller magnitudes they occasion compressive stresses in the reinforcement. A perfect bond between the metal and the concrete is of course assumed. Considere cites a case where a 1:3 mortar reinforced with 5½ per cent. of steel sustained a shrinkage of 1-100 of one per cent. in its length. This would occasion an initial compressive stress in the metal of approximately 3,000 pds. per sq. in. There can be little doubt that such initial stresses do exist but as to their actual magnitude, little with certainty is known. While their presence in this instance has not been wholly ignored, no attempt to consider their magnitude and effect has been made.

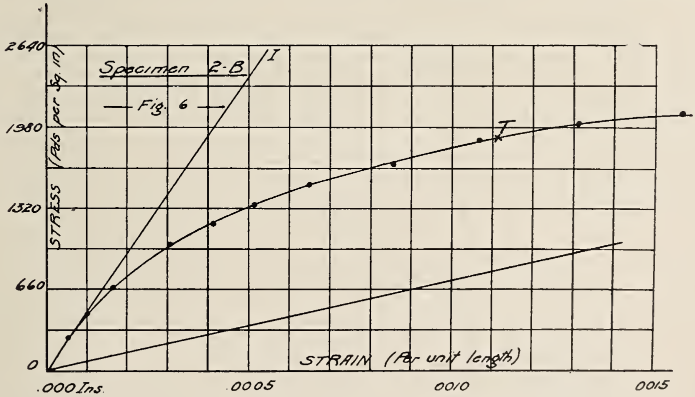


As stated above, the features of the stress-strain curve for concrete as obtained by compressometer tests is the variation of its inclination to the axis of strain. This is interpreted as meaning that the material loses rigidity as the stress is increased and that the so-called modulus of elasticity meanwhile grows less. It was thought worth while, in order to get a comparison between working stresses and factors of safety in the two

REINFORCED CONCRETE COLUMNS

$2\frac{1}{2}$% Steel Reinforcement





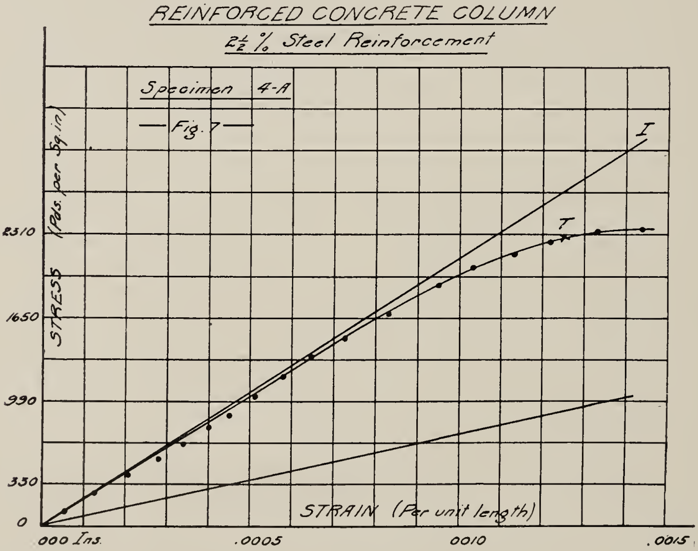
materials, to find for a working stress of 500 pds. per sq. in. in the concrete, the modulus of elasticity of that material. This was done by finding with a pair of dividers, that point on the diagram where the vertical intercept between the line for steel and the plotted curve, was the graphical equivalent of 500 pds. per sq. in. The corresponding strain was noted and from the equation, $E_c = c/s$ where E_c is the modulus of elasticity for concrete, c the stress, and s the strain, the modulus of elasticity was found. This quotient of course will give what might be called the *average* modulus of elasticity covering a range of stresses from zero up to 500 pds. per sq. in. The corresponding stress in the steel was found from the equation $f = E_s s$, E_s being taken as 30,000,000.

The factors of safety given in the following table are based on an ultimate crushing strength of concrete equal to 1,720 pds. per sq. in. and an ultimate strength in steel of 66,400 pds. per sq. in.

Moduli of Elasticity of Concrete Corresponding to a Working Stress of 500 pds. per sq. in.

Column	E_c	Stress in Concrete	Strain	Stress in Steel	Safety Factor-Concrete	Safety Factor-Steel
1 B	1,400,000	500	.00036	10,800	3.4	6.1
2 A	1,900,000	500	.00026	7,800	3.4	8.5
3 B	1,700,000	500	.00029	8,700	3.4	7.6
4 A	1,360,000	500	.00037	11,100	3.4	6.0
Average	1,590,000	500	.00032	9,600	3.4	7.0

The anomaly from the above table is that at such a moderate stress as 500 pds. per sq. in. in the concrete, the factor of safety should be nearly twice as large in the steel as in the concrete.



For this, no very satisfactory remedy seems to offer itself. There certainly could be no valid objection to utilizing stresses, in such steel as here employed, up to 16,000 pds. per sq. in. But unless we care to raise the working stress in the concrete above 500 pds. per sq. in. we must be satisfied with low working stresses in the steel. The stresses manifestly will always be proportional to the moduli of elasticity of the two materials. Evidently the most economical combination would be the somewhat unusual one of high working stresses in the concrete, with low modulus of elasticity. This would tend to an equality in the safety factors of the two materials.

It will also be noted on the diagram that a tangent line has been drawn in each case to the initial direction of the curve. This line represents the initial modulus of the material. The initial modulus of the concrete can now be found by eliminating the value for the steel, according to Talbot's method as previously mentioned. This initial modulus is sometimes employed in theoretic investigations since it corresponds to working values, which are the maximum values with the usual safety factor employed. The following are the values of the initial modulus of concrete for each of the columns tested. There appears to be considerable variation but the average value compares favorably with published determinations.

Column	E_c (Initial Modulus)
1 B	1,710,000
2 A	2,680,000
2 B	3,800,000
3 B	1,840,000
4 A	1,400,000
No. 1	2,630,000
No. 2	2,340,000
Average	2,350,000

It will be noticed that the points designated T on the graphs correspond fairly well with the strain at the elastic limit of the metal, viz., .0014. The modulus of elasticity for the concrete was found for this point also, the method adopted being that previously described. The results are contained in the table below:

Modulus of Elasticity of Concrete at the point T.

Column.	E_c
1 B	710,000
2 A	940,000
3 B	1,100,000
2 B	1,000,000
4 A	1,080,000
Average	966,000

Evidently, for stresses accompanying or approaching the elastic limit of the steel, an approximate value for E_c of 1,000,000 may be taken. This will render n, the ratio $\frac{E_s}{E_c}$ equal to 30 if E_s, be taken equal to 30,000,000 as above.

Now where a column is reinforced longitudinally, it can be

readily shown that the strength per unit area is given by the equation $c' = c\ [1 + (n - 1)\ p]$
where c' is the stress based on total cross-section,
c is the stress in the concrete,
n is the ratio $\frac{E_s}{E_c}$ for the stress c and
p is the ratio of metal to concrete.

This equation supposes that the two materials deform together and that the concrete adheres perfectly to the steel. The greatest stress in steel to which in fairness, this equation might apply, will be the elastic limit here taken as 42,000 pds, per sq. in., and for this stress, E_c was found to be approximately 1,000,000. The stress in the concrete for such a strain (.0014) will then be 1,400 pds. per sq. in. Applying our formula and remembering that $p = \frac{2\frac{1}{2}}{100}$ or $\frac{1}{40}$, we have $c' = 1400\ (1 + \frac{29}{40})$

$$= 2415 \text{ pds. per sq. in.}$$

With the stresses, that *did actually* occur at the elastic limit of the steel, as revealed by the graphs, this stress, 2415, may be compared. The table supplies the data:

Col.	Total Stress.	Stress in Steel.	Stress in Concrete.
1 B	1930	42,000	880
2 A	2400	42,000	1350
3 B	2680	42,000	1630
2 B	2055	42,000	1005
4 A	2370	42,000	1320
Average	2280	42,000	1230

We find therefore that the average total stress differs by less than 6 per cent. from the theoretic value 2415, and the average stress in the concrete, 1230, differs from its theoretic value 1400, by less than 12 per cent. Beyond this the formula should not be pressed. As to the distribution of the total stress between the steel and the concrete in the region beyond the elastic limit, nothing definite is known. Further, the value of n in such case is assuredly indeterminate and any assumption as to its value must in the nature of things be questionable. Considere succeeded in proving, with Coulomb's theorem as a basis, that the resistance given to sand by hooping is 2.4 times greater than the direct resistance of the longitudinal reinforcement of the same weight when the tensile stress in the former is equal to the compressive stress in the latter. He concluded that the same principle is true of concrete. The assumption was made, however, that the hoops are close together (from 1-4 to 1-10 of the diameter of the spiral). The efficiency of hooping depends on its capacity to resist lateral swelling and as the elastic lateral swelling is small, relative to the longitudinal strain, (Talbot gives Poisson's ratio for concrete as equal to 1-8) the hoops will certainly contribute little to the strength of a column for moderate loads. Such reinforcement is, however, quite effective in increasing the ultimate strength of a column, for, under increased loading, ultimate failure is prevented by the circumferential bands. Finally failure will occur by the excessive stretching of these bands or possibly by their rupture.

In the columns tested, series A were reinforced by hoops, series B by spirals having a pitch in each case of 3½ inches, equal, in fact, to the shorter diameter. Such a pitch is very much greater than Considere contemplated and hence it may be considered scarcely proper to institute a comparison between the values obtained from the equation and the strength as revealed in the testing machine. That the pitch was altogether too great was shown in at least one instance where, during the progress of the test, both concrete and the longitudinal rods bulged outward between two consecutive spirals. See photo, column 1-B.

In accordance with Considere's principle and considering also the presence of the longitudinal rods, the strength of the column will be given by the formula

$$P' = f\ (A_s + 2.4\ A_h) + \mathrm{A}\ (1 - p)\ c$$

where P' is the total load on column,
A_s is area of steel in longitudinals,
A_h is equivalent area of steel in hoops, if converted into longitudinals of same weight,
A is total area of cross-section and
c is compressive stress in concrete.

Now

$$P' = nc\ (A_s + 2.4\ A_h) + A\ (1 - p)\ c.$$

$$A_s = \frac{2½}{100} A \text{ and } 2.4 A_h = .012\ A.$$

When $c = 1400$, $n = 30$,

$$P' = 1400\ A\ [30\ (.025 + .012) + \frac{39}{40}]$$

or $P' = 1400\ A\ (1.11 + .975)$
$= 1400\ A \times 2.085.$

Dividing by A to obtain c', we have

$$c' = \frac{P'}{A} = 1400 \times 2.085$$

$$= 2926 \text{ pds. per sq. in.}$$

If for 1400, we substitute 1720,

$c' = 3590$ pds. per sq. in.

The propriety of applying this equation in the second instance may be questioned on account of the uncertainty of the stresses produced in the longitudinal reinforcement, and in the hoops. Yet, even in the former case, the result, 2926 pds. per sq. in., is so much greater than the average stress actually reached, that it is doubtful if the hoops contributed anything to the strength of the columns. In other words, the presence of the longitudinals seems to be capable of accounting for the stresses actually obtained.

Two compressometer tests were made on plain concrete columns of the same sectional area, the span between collars being 15 inches. The stress-strain curves are shown in figures No. 1 and No. 2. For the purpose of comparison, a modulus of elasticity for each was determined for stresses of 500 pds. per sq. in. and also at a strain of .0014 as was done for the concrete of the reinforced columns. The results are given in the table following:

Plain Concrete.

No.	E_c at stress 500.	E_c at strain .0014	Ult. strength
1	2,630,000	1,060,000	1542
2	2,200,000	1,100,000	1744

Apparently the earlier modulus is somewhat larger than in the cases where the columns were reinforced. The later modulus, however, remains practically the same, showing that the hooping in this instance has contributed nothing to the stiffness or rigidity of the concrete which it encloses. We must not lose sight of the fact that the explanation of these phenomena is probably due to the wide spacing of the rings of metal. These tests as might be expected, lead to no conclusions as to the comparative merits of spirals over hoops or vice-versa.

Conclusions.

1. The employment of longitudinal steel reinforcement in concrete columns is not economical except where high working stresses in the concrete accompany a low value of E_c.

2. The hoops and spirals in the cases examined contributed little or nothing to the strength of the column beyond what could be explained by the presence of the longitudinal rods.

3. The hoops and spirals did not increase the rigidity of the concrete which they enclosed. These two phenomena may be explained by the fact that the pitch of the hoops was much greater than is considered good practice.

4. For columns up to 25 diameters, the tendency to fail by buckling under centrally applied loads is probably small.

5. For this particular class of concrete a modulus of elasticity of 1,500,000 for a stress of 500 pds. per sq. in. seems to be a fair value.

6. The variation in the ultimate strength values of the separate columns would indicate the necessity of employing a fairly high factor of safety in the use of reinforced concrete columns for construction purposes.

BABBITT BEARINGS FOR HIGH SPEEDS

HARRY H. ANGUS, B.A.Sc.

Until the advent of the steam turbine, high rotating speeds were seldom met with on large works, and when the turbine first came into use, the flexible shaft system of the De Laval turbine and the sleeve type of bearing used on the Parsons turbine were the only ones in common use. It was thought at that time that babbitt bearings could not be used successfully for high speeds on account of their inability to take up the vibrations caused by the rotating body being out of balance.

However, by using babbitt bearings for low speeds and gradually experimenting with them at higher speeds, it has been found quite practicable at the present time to use them with speeds of 2,500 R.P.M. or more. The taking up of the vibration is no doubt due to the fact that at high speed, the journal is separated from the bearing by a film of oil which thus allows it the same motion as in the sleeve type of bearing. Success in using babbitt bearing for high speed has no doubt also been due to some extent to the better facilities for balancing rotating bodies and also to the development of a special type of babbitt bearings suitable for this work.

In this class of work the clearance between the bearing and the shaft should range from .002 for 1″ shaft to .01 for 6″ shaft and .02 for shafts 12″ or more in diameter. If the clearance between the shaft and the bearing is too small the expansion of the shaft, if the speed is raised quickly, will cause binding. In the design of bearings it is usual to keep the peripheral velocity of the journal below 75 feet per second and the pressure below 80 lbs. per square inch of projected area of the bearing. Of course as the pressure is decreased, the speed may be increased or vice versa. In come recent tests with a large rotating body of 25 or 30 tons it was found that the bearing ran well with a pressure of 300 lbs. per square inch and a peripheral speed of 80 feet per second, which shows that the above limits are quite low. It is usual to make the length of the bearing three times the diameter as in ordinary bearings but probably 2½ to 1 or 2 to 1 would give better results.

Formerly a great many of the larger bearings were cored out for the purpose of supplying cooling water to the bearings. It has been found, however, that this is not necessary if the bearings are well proportioned and the oil supplied in generous quantities and well cooled before being used again. As bearings are usually enclosed in pedestals, not more than one-third of the heat generated is taken away by radiation and by air, leaving by far the greater part to be carried away by the oil. It is best in this work to have the oil flow into the bearing from a gravity system under a head of a few feet, thus insuring a very liberal supply of oil. After going through the bearing the oil is cooled and again pumped back into the gravity tank and being out of contact with the air is kept pure and can be used over again. In this way the same oil can be used for several months before an addition of new oil is necessary.

The bearing should be constructed on the ball and socket principle so as to readily take up the alignment and should also be provided with an accurate means of adjustment in any direction. If the bearings are not very carefully lined up there will be excessive vibration and heating. As there is no metallic contact in high speed bearings, the bearing metal is of small importance except that it is best to have some soft metal in order to save the shaft, in case of any failure in the supply of oil. It was found by test with a 15″x40″ bearing (see Transactions of American Society of Mechanical Engineers, Vol. 27) that the thickness of the oil film varied from .0019 at 460 R.P.M. to .0032 at 1050 R.P.M. and at about 300 R.P.M. there was metallic contact of the journal with the bearing which could be noticed owing to the rapid increase of friction around this point. These tests are cited merely to show that there is no metallic contact at high speed and that for this reason the quality of the bearing metal which is so important in slow speed bearings is of little importance with high speeds. It is, however, important that the babbitt metal be well fastened in the bearing and it is well to cast the babbitt in the bearing then rough bore and afterwards pean well and bore true to size.

In regard to the oil grooves, the best results will be obtained by having a single oil groove along the top of the bearing parallel to the axis of the shaft. The oil is fed to the centre of this groove and runs along it and is carried around to the surfaces in contact by centrifugal action. In some classes of bearings where there is no upward thrust it is possible to do away with the greater part of the babbitt in the top half of the bearing, thus allowing the oil to cool the shaft much more easily than otherwise.

Another point which it is well to look after is to see that the bearings are eased at their sides. This does away with any wedging action which may occur when the two halves of the bearing are bolted together and which is liable to cause binding, and in addition gives the oil a much better chance to do its work. The sharp edges of the bearings tend to wipe the oil from the shaft but if the bearing is eased away for about 25° above and below the centre line, the oil will enter the bearing surface nearly at a tangent and is thus more easily drawn in. It will be found that the loss in bearing surface area is more than balanced by these advantages.

APPLIED SCIENCE

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Editorial

A Reference Library

Improvement of technical courses is effected in many ways. Ability on the teaching staff, though a prime requisite, will not do all. There are certain aids which no efficient engineering college can afford to dispense with. For instance, in the teaching of Bridge and Structural Design, it has been found that collections of photographs, lantern slides and plans of typical structures are very helpful accessories. The larger Schools of Applied Science on this continent possess very fine equipment of this sort and not only are undergraduates and those academically connected benefited, but all interested persons have at their disposal, for purposes of reference, exceedingly valuable "libraries" of illustration. If such repositories had not been established by technical colleges, they probably would not yet exist, since much care and trouble must be taken in gathering together a large number of illustrations which will comprehensively represent the history and present practice of a given branch of engineering.

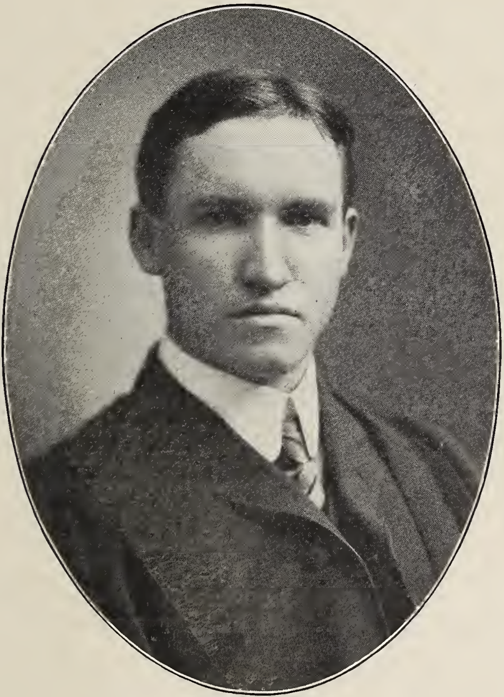
Recognizing the aid which would be afforded to those interested in Bridge and Structural Engineering by equipment of the above described kind, the Faculty of Applied Science and Engineering of the University of Toronto has recently brought its needs in this respect before a large number of bridge companies, and is pleased to find them willing to contribute valuable illustrations of their work as a nucleus to a collection. A number of interesting photographs have already arrived, and many more are likely to follow. It is hoped that those graduates who are engaged in bridge and structural work will supplement the collection by such photographs or plans as they may think of interest. The University is dependent largely upon the loyalty of its graduates for help of this kind, and more should be expected of them than of business corporations, many of which have no connection through their heads to our alma mater.

1908-09 Calendar.—The calendar of the Faculty of Applied Science for 1908-1909 has just been issued. Its contents have been entirely rearranged and improved. One item giving notice that after 1908 the course in Engineering may be lengthened by another year will interest all graduates. Copies may be had on application to the secretary.

OBITUARY

HARRY G. SMITH, B.A.Sc.

To many of those connected with the Faculty of Applied Science, whether as students or as members of the teaching staff, the early days of July brought a painful shock in the announcement that Harry G. Smith, B.A.Sc., '04, had lost his life in the waters of a lonely northern lake. To every one who had known him there came but one feeling — a comrade had gone down somewhere along the line.



Harry G. Smith

After preparation at the St. Catharines Collegiate Institute, Mr. Smith entered the Faculty of Applied Science in the department of Mechanical and Electrical Engineering, graduating with the class of '03, and taking his degree in '04. Always a conscientious student, he frequently carried himself to the limits of endurance in his work. When under graduate days were over he became attached to the teaching staff as Fellow, and afterwards as Demonstrator, in Electrical Engineering, which position he held at the time of his death.

This untimely close of a useful and promising life came while on a prospecting expedition to New Ontario, whither he had gone last May. After a long and arduous trip to Gray's Lake, he and his partner were returning by way of Obabika Lake, and were camped on the shores of Lake Wakimika when the unfortunate accident occurred. Mr. Smith was trolling alone in the canoe, when by some mischance the latter upset and threw him into the water, blowing out of his reach almost immediately. Entangled in the trolling line, as he was, the waters of Wakimika claimed him before aid arrived.

HARRY W. ARENS

Many friends in the University were shocked to hear of the death, during the summer, of a recent graduate, H. W. Arens. Mr. Arens received his early education in the public and high schools of Orillia. After leaving the high school he spent four years in the machine shop of the E. Long Co., Orillia, and came to the S. P. S. in the fall of 1901 to take the M. and E. course. He graduated in 1905, and on leaving the School went to Winnipeg. He was succeeding remarkably well in his profession when he fell a victim to consumption and had to give up all work last winter. His death took place at the home of his parents in June of last year.

OSBORNE CORRIGAN

Osborne Corrigan, of the third year School of Science, died at the Toronto General Hospital on May 6th of last year, of illness brought on while he was with a prospecting party in Northern Ontario. After completing the second year in the analytical chemistry course Mr. Corrigan left on a prospecting trip. When the party had reached a point some sixty miles north of Latchford, he was taken ill, and the only hope of saving his life was to get him to a hospital as quickly as possible. The task was undertaken by P. Lennox and Bert Rogers, assisted for part of the way by Herbert Aikens, of the third year in the School of Science. By five days of heavy sledging, impeded by great drifts of snow, the sick man was brought into touch with civilization, and soon after placed in the General Hospital. It was too late, however, and Mr. Corrigan soon after succumbed.

Corrigan stood well with his year, and his death came as a great personal loss to many men of the University.

Mr. Rogers and Mr. Lennox have since been honored by the Royal Humane Society for their brave attempt to save Mr. Corrigan's life.

OUR CONTRIBUTORS

C. H. C. WRIGHT, B.A.Sc.

Charles Henry Challenor Wright was born on board the British barque "Frank" in Chelsey Harbor, Mass., in 1864, his early childhood days being spent in Digby, N.S. His father, William Wright, was captain of a merchant liner, sailing from St. John and Boston, which was lost off the coast of the West Indies during the famous cyclone of 1867. There was but one other child, Minnie J. Wright, in the Wright family. C. H. C. had just got nicely started at the public school in Digby, N.S., when his mother married J. J. Cameron, a graduate of Dalhousie, and the family moved to Kingston, Ont., where Mr. Cameron proceeded to take a course in Theology at Queen's. During these three years C. H. C. attended the public school in Kingston until his stepfather accepted a charge in Shakespeare, Perth County, and Charles Henry had another taste of public school life, passing his entrance examination to the High School in 1878 and proceeded to attend the Collegiate at Vienna. In 1880 his stepfather left Shakespeare, removing to Pickering, Ont., and Wright entered the Pickering College, where he was soon to make the acquaintance of J. E. Bryant, its principal, from whom he received his mathematical inspirations. In 1881 he passed his Second Class Teachers' examinations. About this time he became inspired with the idea of coming to the "School" and during the fall term of 1881 paid special attention to Mathematics, Science, English, French, Latin and Art. In September, 1882, he went to the Model School in Whitby and in January, '83, began teaching in a school a mile and a half east of Pickering, where he remained until '85, living at home in Pickering and taking certain classes in Art at Pickering College under Professor Shrapnell. During this time our professor-to-be was keeping up his mathematics under the direction of some of the staff of Pickering College and incidentally playing football and cricket on every possible occasion, winning several of the field sports prizes, and filling in his spare time at the gymnasium, obtaining the championship in 1881 and 1882.

In the fall of 1885 he registered as a student at the School and his subsequent history is one of triumphs. There were thirty-five men entered the "Little Red Schoolhouse" which was very small in those days, the same year as C. H. C.

On the completion of his first year, out of twelve subjects, he captured ten first places; his second year exams. found him less fortunate, but still with nine places out of thirteen subjects, and in 1888 he graduated, together with sixteen others, obtaining twelve first places out of fifteen subjects and capturing the coveted prize in each year, which required not only that the student stand first in his class, but should also obtain an average of more than seventy-five per cent. of the possible marks.

During his second year he was appointed representative to the Engineering Society, and was made vice-president of the same society in his final year, Dr. Galbraith being president.

Wright was a member of the first tug-of-war team which won the trophy for the School, not to be surrendered again by them for many years. His vacations, while at the School, were spent with H. B. Proudfoot, Civil Engineer and Land Surveyor, and the summer of '88 with J. Tiernay, both in the Temiskaming district.

During the fall of '88 he taught in the Lindsay High School and in the spring of '89 went to Boston to work for Woodbury & Leighton, building contractors, as draughtsman, soon becoming chief of the estimating staff. In the fall of 1890 he secured the position of lecturer in Architecture at the School.

During his term as lecturer at the School he acted in conjunction with a committee from the Canadian Society of Civil Engineers, in an effort to establish a Canadian standard for cement tests and through experiments performed at the School was of great assistance in establishing a reputation for Canadian brands of Portland cement. He also carried on a series of tests on brick, brickwork, masonry, terracotta and stone, the results of his labors in stone tests being published by the Ontario Association of Architects, and those of the brickwork, masonry and terracotta published by the Engineering Society of the School. He also read a paper before the O. A. A. on "The Behavior of Steel under Stress," and later worked out an aspect compass for the architects. In Statics he discovered that the Vertical Shearing Force diagram represented the Bending Moment and developed a general solution for the Fink Roof Truss. Working in conjunction with W. J. Loudon he invented apparatus for the teaching of statics.

During the whole of his School days Prof. Wright was an all-round sport, playing Association football in various capacities on the foremost teams in the Dominion. It might be stated that even after he joined the staff of the School he continued to play football and even now his inclinations are in that direction. Those who were his fellow students say that he was a general favorite, active in everything in which the students were interested but seeming to have an insatiable desire for standing in front of the draughting board, sometimes being known to turn out nearly twice as many drawings as called for in the curriculum.

The Madawaska Club, organized in 1896, found an active member in Prof. Wright and if you wish to bring a smile to his lips ask him to tell you about the car-load of window-sash which he and W. J. Loudon took up Georgian Bay way and following on the heels of this will probably come some interesting information regarding the founding of the "Go Home" colony on the Go Home river.

Of the man as we know him now it may be said that every student has a friend in Prof. Wright and there is probably no member of the present staff who is more completely in touch with student affairs; he is energetic, powerful along lines needing executive ability, knows men well and how to handle them, kind-hearted and anxious to perform to the best of his ability anything which seems to be outlined to him as his duty.' He has the interests of the School at heart and is giving his life to work out his ideals for the future of the Faculty of Applied Science. The fact that he is still a comparatively young man gives us cause for congratulation since we see for him many years to come of useful and efficient work.

B. E. FERNOW, DEAN OF THE FACULTY OF FORESTRY

Bernhard Eduard Fernow was born in the Province of Posen, Prussia, 1851. He graduated at the gymnasium at Bromberg; entered the profession of forestry, following the regular prescribed courses for Government service at Muenden Forest Academy, and also studying law at the University of Koenigsberg. He served his year in the army during the Franco-German War, 1870-71, and became lieutenant of reserves. In 1876 he emigrated to America, and engaged in metallurgical business, and later acted as consulting forest engineer. He served as secretary of the American Forestry Association (formerly Congress) 1883-87, and from 1887 as chairman of its Executive Committee, and later as its first vice-president. He was made Chief of the Division of Forestry of the United States Department of Agriculture at Washington in March, 1886, and continued in that office for twelve years, when in 1898 he became Director of the New York State College of Forestry at Cornell University, the first institution of its kind in the United States. After the close of this institution in 1903, due to political intrigue, he acted in private practice as Consulting Forest Engineer, besides giving several courses of lectures at the Yale Forest School. In 1907 he was called to Pennsylvania State College, to organize a forestry school on the same lines as the Cornell school, from which position he was called to Toronto University for the same purpose. He was made an honorary LL.D. by the State University of Wisconsin in 1897, and later by Queen's University. He was made a fellow of the American Association for the Advancement of Science; a life member of the American Institute of Mining Engineers; an honorary curator of the National Museum; an honorary member of the Scotch Arboricultural Association; of the Academy of Science of St. Petersburg; of the Pennsylvania Forestry Association, and an active member of various scientific societies of the United States. He is the author of Economics of Forestry, a full treatment of the subject, published by T. Y. Crowell & Co., New York; has completed a new book on History of Forests and Forestry in the United States and other countries, and is publishing the Forestry Quarterly, the only strictly professional journal of forestry in the United States. He has also been the author of many official reports, bulletins and other publications of professional or propagandist character, establishing the science of forestry in the United States.

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CANADA'S FERTILE NORTHLAND

R. E. YOUNG, D.L.S.

Mr. Young after thanking the president and members of the Society for the invitation extended to him to address them, spoke as follows:

At the outset I wish to point out to you that I have evidence at considerable length for every statement that I intend to make here. The large map of the Dominion* on my right shows, colored in red, the townships that were surveyed on the 1st January of this year, the townships of which plans have been published. The settlement is, of course, confined to the areas colored in red. You will notice a small patch of darker red color around the city of Winnipeg. That is the land that was surveyed according to a departmental map issued in the year 1873. It is interesting to examine the original because immediately outside the limits of the surveyed townships the land is shown topographically in a very incorrect manner. According to that map the information about the country outside the surveyed area was very limited indeed. There are about 4,500,000 acres of land in that small tract that was surveyed in 1873.

The subject of my story to-day is the portion of the Northwest north of the colored area.

I want to devote a few minutes, if you would allow me, to an explanation of the progress in the colored portion as shown on the large map. There are three reasons why.

When I bring before you in the manner which I shall endeavor to do the facts that I have in my possession to-day the growth in that settled portion will appear surprising and interesting; and the growth that we may expect in the settled portion in the future will show that it is of great importance that we should know and investigate more about the country north of the colored portion. If that region is as good as I think it is, investigation is very necessary, and if it is as bad as some people imagine, it is equally desirable that we should ascertain all that we can about it.

There is another reason why I want to explain a little about this colored portion on the map, and that is because I think I can show you in a very brief way and with very few figures, that the area of land available in the surveyed portion of the Northwest is much more limited than many people imagine.

There is a third reason, a personal one, and perhaps you will allow me to state it, and that is, I was a resident of the Northwest for nearly twenty years and I lived there through all the dark years when we hoped that many things would happen which have since come to pass, and our faith in that country was sorely tried. I like, therefore, to dilate upon the progress that is now taking place and to tell you a little about what we expect will happen in the future.

It is a little difficult to explain these things by figures without it becoming wearisome and I am going to illustrat some of my points by diagram.

First let me point out the railways. There are nearly 7,000 miles of railway on that map in the three prairie provinces. The exact figures were 6,422 on the 1st July last year, and therefore, it will be safe to say that there are 7,000 miles of railway now. When I landed in the Northwest on 1st May, 1880, the railway mileage in the Northwest consisted of a half finished line between Emerson and St. Boniface. We had to cross the Red River into Winnipeg on the ferry. The line was built by laying ties on the prairie and spiking the rails to them and that is all the railway there was.

The population in the settled portion of these three provinces can be safely stated at 1,000,000 people. The Census Bureau has given me an estimate of 6,800,000 as the total population of Canada on the 1st January last so that we have in the three provinces, excluding British Columbia, one-seventh of the population of the Dominion at this date.

Now I want to illustrate by means of diagrams some of the figures to which I will draw your attention. There are 120,000,000 acres on the colored portion of the map to my right and I have converted that into a square on the same scale. I do not know that I could show it in any better way. Here is a square on the same scale representing the colored area on the map (holding up square). The area of land alienated is 86,000,000 acres which is represented by the somewhat smaller square and which I place in front of the larger square. The balance around the edge is what we have left in the surveyed portion of the Northwest. I am giving you round figures although I have the figures exactly. Now let us compare the area alienated with the area under cultivation of 8,500,000 acres represented by this much smaller square. The area under wheat is 5,000,000 acres represented on the same scale by this still smaller square.

This smaller square represents as I say 5,000,000 acres of land but it also represented 100,000,000 bushels of wheat in 1906. Supposing I take the 86,000,000 acres of land and cut off a quarter for the purpose of making a calculation which may seem to be a rather optimistic one. If I scale the 86,000,000 acres down in that way to 65,000,000 acres and divide the 5,000,000 acres into it it will go 13 times. Is it not a fair supposition that we can multiply 100,000,000 by 13 and get 1,300,000,000 bushels of wheat within a reasonable number of years? If you feel inclined to doubt that supposition, gentlemen, there is just one point I ask you to remember: that is selected land. It is not land taken at random over an unexplored country; it is selected land. Over 31,000,000 acres of that land was selected by about 200,000 homesteaders. About the same amount was selected by seven or eight railways to satisfy their land subsidies, selected by expert land examiners; and while I would not pretend to be an authority on this subject and to make the statement that there will be raised annually 1⅓ billions of bushels of wheat, for the purpose of my argument I want to just ask you to turn that amount into dollars and consider it for a moment. We are not taking into account oats, barley, flax or rye, or the cattle products of that country at all. Take that area of land with the wheat which can be grown to a lesser extent even than my figures would give, and it seems a reasonable and safe statement to make that in the time of people now living there will be the equivalent in money of 1,300,000,000 bushels of wheat. Remember there are over 50,000,000 acres of land that have not gone into that calculation. There are 120,000,000 acres of land surveyed and I am only asking you to consider this as applied to 65,000,000 acres.

There is another aspect of this question that I would like to bring to your notice. I have a telegram here from a gentleman at Saskatoon, and he followed that message up by a letter. I got these figures because I knew the gentleman, and I particularly asked him to give me figures that I could absolutely rely upon and quote. I only got figures from that point although similar results can be shown from many other points in the West. I have no interest in Saskatoon in any way; I do not own an acre of land there or anywhere else in the Northwest, and do not expect to. Now this gentleman's statement, which I consider very striking, is:—"375 acres wheat, net cash yield per acre 14⅓ dollars." It is quite a striking thing to reflect upon. That man goes into that country and farms 375 acres. He spends $6 or $7 in raising wheat on it, and after the crop has been harvested he has over $14 per acre to put into the bank.

Now about the North country. In considering the North country a great many people have the idea that latitude governs the climate. Of course that is absolutely untrue. It is ridiculously untrue, particularly as regards our country. I will go into the climate question in a few minutes. Let me draw your attention to the fact that that northern region is practically all a wooded country. The knowledge we have of that country has been obtained by people who have travelled along the rivers in canoes almost entirely. I would like to ask any gentleman to try and imagine how much valuable knowledge would have been obtained of the great and wealthy province of Ontario by means of travelling along the St. Lawrence, the Ottawa and other rivers as men used to travel in canoes 200 years ago? And yet that is the kind of knowledge that we have about that North country almost entirely.

Let me ask you to notice a small red star on the map, 14 miles outside the arctic circle. That is Fort Good Hope on the Mackenzie river. The statement was made before the Senate Committee last spring which was investigating the North country, that potatoes, cabbages, and onions were grown at Fort Good Hope.

A gentleman, who gave evidence before the Senate Committee last spring, was in my office about a week or ten days ago. He told me that he was at Fort Good Hope last summer and he said: " I saw just as good vegetables growing there as I have seen in the Province of Ontario." The gentleman in question is Mr. Conroy of the Indian Department. The growth of vegetation is rapid, beyond belief to us, in that North country. I will quote you a statement made by Bishop Clut, who I think was stationed at Fort Providence for many years, and who gave evidence before the Senate Committee, which was presided over by the late Senator Scultz, in 1888. He said, speaking of vegetation at Fort Good Hope; " I have observed this phenomenon: Towards 7th or 8th June, vegetation commences, and in five or six days the leaves of the trees had reached their natural size."

I will proceed to tell you what the red spots on this map mean. Those are points where wheat has been grown. They were not selected for any agricultural purpose, because they are points where the fur trade has been carried on by the Hudson Bay Company. Another point I would like to mention to you is that the inhabitants of that country, and there are very few of them, are almost exclusively flesh eaters. They do not eat, and they do not desire to eat, wheat or such products; I want to show you—no doubt many of you have seen it before, but it seems to me important—a sample of Ladoga wheat that was grown at Fort Simpson. Here it is (holding up sample). I got it from Doctor Saunders, Director of Experimental Farms. Fort Simpson is the farthest north of these red points just short of latitude 62 or just about it. That wheat was shown to a gentleman who is accounted an authority on the subject, you could not get a better authority, with the request, " Would you please look at that wheat, but do not refer to the label on the bottle, and tell me what you think of it ? " He examined the sample in the way that men who are experts on wheat often do.

He saw nearly every grain of it. He said: "It is very nice wheat, I would call it good wheat. It has been slightly frosted but I think that wheat would go about 64 pounds to the bushel." Well the label on the sample says, "Ladoga Wheat, grown at Fort Simpson on the Mackenzie river, 62 pounds to the bushel."

Here is a sample of wheat from Fort Vermilion (displaying sample). That also was shown to the same expert. In both instances he expressed his opinion before he knew where either of the samples came from. He said: "That is pretty nice wheat. It is not so nice a wheat as the other, but I think it would make first rate flour; it is good wheat." Now consider for a moment that the area enclosed by these red spots would be larger—I think considerably larger—than the entire province of Ontario. I will just take a moment to enumerate these points. There is Fort Simpson on the Mackenzie river, Fort Providence—and a witness said before the Senate Committee last spring that he had seen wheat ready to cut at Fort Providence on the 28th July, 1906, and it was cut a few days later and good crops of oats and barley—Fort Liard. You see in the Report of the Senate Committee of 1888 that Ex-Judge McLeod gave evidence and quoted from his father's Journal. His father was an official of the Hudson Bay Company and his Journals extend from 1811 to 1849. He said: "Wheat is a sure crop at Fort Liard four times out of five." Then there is Fort Chipewyan. Wheat that was grown there took the highest award I think at the Centennial Exhibition in 1876. Then there is Fort Vermilion, where a flour mill is turning out 35 barrels a day. That mill is electrically lighted and equipped in a modern manner. There were 25,000 bushels of wheat grown at Fort Vermilion in 1906. This farthest point west on the Peace river is Fort Dunvegan. (There are two or three other points—Hudson's Hope and Fort St. John—which I have omitted on account of their being down in the valley). Proceeding with the reference to the wheat points, there are Lesser Slave Lake, Fort McMurray, and Ile a la Crosse. At the latter point Professor Macoun found them growing wheat and grinding it with a horse-power mill in 1875. Then there is Stanley Mission,—150 miles north of Prince Albert on the Churchill river,—Archdeacon McKay gave evidence before the Senate Committee that wheat had been grown for seven years in succession at Stanley Mission. At Cumberland House, Sir John Richardson records that wheat was grown in 1820 when he passed through there. We also have the statements of witnesses before the Senate Committee that wheat has been grown at Norway House, Cross Lake and Nelson House.

There have been a great many statements made about the probable area available in that country for settlement. One gentleman, a member of the Alberta Legislature, Mr. Bredin, said (I am quoting his statement though I think it rather a liberal estimate), that there was 100,000,000 acres of land—he was particularly referring to the area as far east as the Athabaska and west and north of it—available for settlement. Mr. Conroy of the Indian Department, who has travelled over that country a great deal, made the statement that there was as much land in that tract of country as was now settled west of Winnipeg. There is a great deal of evidence existing as to the probable area of land available in that country. The Minister of the Interior had an exploration made, I think it was in 1905, of the country between Pas Mission on the Saskatchewan and Fort Churchill. That party was sent out for the purpose of exploring the country. They were members of the Geological Survey of Canada, and their statement—which I presume can be absolutely relied upon —amounts to this: That there are 10,000 square miles of good clay land between the Pas and Fort Churchill—6,000,000 odd acres of land. A surveyor of the Indian Department who has been around Lac la Ronge told me that he considered the land surrounding its shores just as good as any land south of the Saskatchewan. There has been a great deal of other evidence given about that part of the country which I will not take time to dwell upon. It may be generally stated that south of the Churchill river, west of the Athabaska and Slave rivers and extending as far north as Fort Simpson, and perhaps a little farther, there is a good deal of good land all the way.

Now as to the climate. Mr. R. F. Stupart, the Director of the Meteorological Service of Canada, has devoted a good deal of attention to this subject, and he says that he would consider the mean summer temperature of 57½ degrees was a safe limit up to which you could grow wheat. He said that he would not dogmatize on the subject but that that would, he thought, be a safe limit. I have endeavored to put on that line on the map as near as I could get to it. I admit the information is not complete, but we have done the best we could from the evidence supplied by Mr. Stupart. I will trace a line on the map running from the north-east corner of the province of Manitoba—just outside the spots that I have mentioned—crossing the Mackenzie river about half way between Fort Wrigley and Fort Norman, and then following the eastern slope of the Rockies southerly. During his evidence before the Senate Committee last spring, Mr. Stupart furnished a table giving the summer temperature, and I think it is a very striking thing that the summer temperature of Fort Simpson, Fort Chipewyan and Winnipeg are nearly the same—that is from the 1st June to the 20th August or thereabouts—the summer temperature would therefore be nearly the same as that of Ontario. It is hard to understand or believe that a man may be going about here in summer clothing and that if he could be transported to Fort Simpson in those months that he could wear the same clothing without discomfort. You may say that it is pretty cold in the winter. I do not think there is any doubt about it. It is somewhat colder than the Northwest. There is just one remark that was made by a witness before the

Senate Committee last spring that seems to me to be very pithy and to the point. He said: "Things don't grow in the winter."

If the agricultural possibilities are in that country, the fact that it is a cold climate in the winter won't deter people from settling there. I have read a few unfavorable expressions of opinion about that country but I never heard of anyone saying that it was not a healthy country. I gave you the figures a few moments ago of the net result of growing wheat in the vicinity of Saskatoon. I believe that it would be a reasonably safe statement to make that better wheat can be grown the farther north you go. Many authorities agree that the farther north you go, almost to the northern limit of the wheat growing area, the better the wheat that is grown. I believe that the statement has been made that wheat has been grown at Fort Chipewyan weighing 68 pounds to the bushel. Men have gone into the most undesirable places on the earth's surface in search of gold and to carry on gold mining. They have gone into the hottest and the coldest and the most unhealthy countries for this purpose. Surely there is no amount of gold mining equal to the results obtained at Saskatoon, viz., 14⅓ dollars net per acre?

To meet the point that would arise in a man's mind about the cold winter, first let me introduce to your notice at this stage something that I have prepared for this meeting. I will fasten it to the map so that you can see it in its relation to the subject. This is a map of the Province of Tobolsk in Siberia. It is drawn to the same scale as the map and placed in the same position as to latitude. The southern boundary of the main part of the Province you will note is about 100 miles north of the latitude of Edmonton. That small dark spot, not quite one-third north of the south part of the province, is the City of Tobolsk. That city has a population of 20,427 people. The City of Onsk on the Great Siberian Railway, just on the south boundary and about 100 miles north of the latitude of Edmonton, has a population of 37,470. The City of Tomsk, which is not within the Province of Tobolsk but in an adjoining province and in a little lower latitude than Tobolsk, has a population of 52,005. The population of the Province of Tobolsk was a million and a half of people in 1900. I also have figures here of the population of some eight or ten towns in the Province of Tobolsk. There is one of 1,000, another of 3,000, another of 7,000, one of 8,000, and so on. The farthest north is the town of Bere-zoff with a population of 1,073 and in latitude 63°.50′. In 1900 there were raised in Tobolsk 6,480,000 bushels of wheat, 3,000,000 odd bushels of rye, 972,000 bushels of barley, and 10,617,000 bushels of oats. These figures are from the Encyclopedia Britannica.

All the information I have would go to show that settlement would not extend to the most northerly regions, but still the fact that there were towns of 1,000 people in the northern portion would go to show that there must be something being done there that would support a town of that size. And two-thirds of the way up we find a road marked on the map which would indicate settlement I suppose.

I have tried to work out some parallel between the climatic conditions there and our own country; I am not able to give it to you exactly, but I am obtaining exact data from the British Ambassador at St. Petersburg which I hope to have in a few weeks. I think that the figures given by the Russian Government would probably be the most favorable that they could furnish. The mean temperature for the period from Sept. 1st to June 1st, which would include the winter months,—I think that is all it is necessary to discuss—would, for the Province of Tobolsk, be practically about the same as in our North country. It is a very striking thing that a million and a half of people live in that province and that they raised 6,480,000 bushels of wheat in 1900. Surely if our country is as good as we think it is we ought to people it to as great and even a greater extent, and to complete the parallel between the two, I think I can say without any hesitation that we have something which they have not got, and that is the benefit of British institutions.

When I was discussing the wheat question in connection with these points that are colored red on this map, I drew attention to the fact that they were not selected for wheat raising. I want to discuss that point a little further. There are three reasons why we can expect better results in wheat raising in our northern country than has been accomplished up to the present time. I will quote what Professor Macoun has stated in a pamphlet relating to the Yukon (reads):

" When grain ripens in the country and is again sown there, it will take on the conditions of its environment and mature earlier, and early frosts, like those attributed to Manitoba, will have no effect, as the crop will mature before they come. I may remark here that the wheat in the Northwest ripens earlier now than it did twenty years ago, and many people believe that it is the climate that has changed, whereas it is only the wheat that has adapted itself to its environment."

I think that any gentleman who has been following the trend of affairs in the Northwest will agree with me that the conditions are better with respect to possible injury by summer frosts now than they were twenty years ago. I don't think that can be questioned. That is one reason that is given. Now I asked a gentleman prominent in the grain trade in the West, and who is better able to express an opinion on the point than I am, a few days ago, what he thought of that statement of Professor Macoun's. He said: " I don't altogether agree with that statement. I do not hesitate at all in saying that the improvement is marked, but I will account for it in another way. If you raise wheat on virgin soil on the prairie it will grow to perhaps the height of a man's shoulder the first year. The next year it will not be quite so high. The third year it will be perhaps not so high as the second year, but it will mature earlier.

Devote that land to some other use for a year or two and then go back to the cultivation of wheat again and you will get the wheat growing to the height of about the second or third year, but it will mature earlier. The soil is sharpened." He explained to me that in the Red River Valley, where the land is heavier, it would take very many years to bring about that result, and it would not be of so much value to this generation; but in the lighter soil farther west it has a marked effect, and as he argued, there is no question about it.

The third reason why we can expect better results in that north country is because the staff at the Experimental Farm, Ottawa, have been steadily carrying on experiments with a view to obtaining a variety of wheat that will ripen a few days earlier: and if they can shorten the term for the ripening of wheat by four or five days or a week, it will bring into the certain line as to wheat growing a very large area of land. They have accomplished some good things already, and they expect to accomplish a great deal more.

There is no question about it that in the north country there are grasses of the greatest possible value to cattle raising, finer grasses than there are in other parts of the Northwest. I could read from a letter written by Professor Macoun on that point. I do not like to pass Professor Macoun's name without saying that I believe that if there is a man whose name will be handed to posterity in Canada with honor it is that of Professor John Macoun, because of the optimism he has always had with regard to that country from the first.

Perhaps I might relate to you a little incident that happened to me in the spring of 1882. I was down at Warren's Landing, at the foot of Lake Winnipeg, about the 1st June, 1882. It was an isolated place to some extent, and rather difficult to get at, and our arrival in June on the first steamer was the first intimation they had there of a great many things which had been happening about the boom at Winnipeg. I was talking with a gentleman there who was connected with the fur trade and had been in it nearly all his life. He was a man of intelligence and was able to talk intelligently about any subject which you might mention, and he was perfectly sane except on one point. I was telling him about all the things that were happening at Winnipeg, and among others the fact that the Canadian Pacific Railway had built enormous shops. He then said: " It doesn't make any difference, Mr. Young, they will be allowed to fall to pieces. That country is no good, it is only good for the fur trade. I have lived nearly all my life in this country, and we old-timers know much better about the country than anyone else." " But," I said, "they are spending millions of dollars in building a line across the prairie." He said, " I don't care, you will find they will take up the tracks." That man was able to talk sensibly about anything else, but there you see was the influence of the fur trade, the influence of the conditions that he was surrounded by; and you will find that time after time when gentlemen in that northern country who had been connected with the fur trade are asked about the country their inclination is always to detract from its value. We hear a lot about the " Last West," our great west, and its value for settlement. I suppose that it is the Last West and I suppose that it is the last, not only for the fur trade of the Hudson Bay Company, but also for other people who are interested in that trade. They are not enthusiastic about encouraging settlement.

There is another point that I want to bring to your attention as to the conditions in the Northwest country. About three weeks ago I wrote to Professor Macoun and gave him a list of questions about that country, to which I asked him to give me answers. I think it is a very remarkable thing that in his reply he says: "In my report to Mr. Alexander Mackenzie, in 1877, just when I was fresh in the Northwest, I gave details about certain districts of the Northland which I could not give in a letter, but I would suggest that extracts from this report may be taken and placed upon file with this letter, as my statements and conclusions as printed thirty years ago still remain without impeachment at the present time." I think it is a remarkable thing that with respect to the country through which Professor Macoun went in 1872 and 1873, and which excited his enthusiasm —this is the country that I am trying to tell you about—he now says of it, "My statements remain without impeachment at the present time." Now he speaks in this letter of two facts that I think are very striking. He says: "In conclusion, I may say that the climate of the whole Northland is a stable one, and as local conditions change it will improve, and where small spots are now called good land, whole areas will take that term. The low altitude and the long day are fixed conditions and will always be the same. The forests will be cleared and the muskegs drained, and as the land becomes drier the frosty conditions will pass away and a great country will result."

Now there are some other sources of wealth in that country. I am going to place this pointer on the pencil line that I have drawn on the map, extending from about the middle of Reindeer Island in Lake Winnipeg northwesterly and crossing the Peace River about fifty miles north of Peace River Landing. That is the line shown on a Departmental publication issued a year or so ago, the mineral map of Canada, as the northerly limit of prospecting. North of that line there is practically no prospecting, as the note on the map says. The mineral wealth of that country is very great. There is no question about it, but that there are a great variety of minerals. The first thing I want to touch on is petroleum. That has been frequently spoken of as the petroleum field of the world, and I will just give you one point about that. Mr. McConnell made an examination of that field some years ago for the Geological Survey, and he made a calculation of the amount of crude petroleum which it would have taken to have saturated the ground to the extent that he had discovered. He says that the amount of crude petroleum sufficient to saturate the area that he had examined would be 6½ cubic miles. A witness before the Senate Committee in 1888, whom I quoted a few minutes ago, Ex-Judge McLeod, said that there was an area of 100,000 square miles in that country within which there were found indications of petroleum. There is a tar spring down at Great Slave Lake, there are some, I think, on the Mackenzie, and there are 75 miles, or thereabouts, along the Athabaska where these tar springs are found, caused by the oozing out of petroleum through centuries of time. I have a photograph here that I can show you of a bank of the Athabaska river, somewhere near Fort McMurray, and I think from the height of the man standing on the bank that it would be about two hundred feet high. It has been represented to me as being solid tar or asphaltum. At any rate, the soil is saturated with petroleum to the whole depth of the bank.

Now as to natural gas. It is a matter well known to many people that there is natural gas in that country. There was a well sunk twelve years ago on the Athabaska, and it has been burning ever since. It is spoken of as the largest gas well in the world. You will find that a great many travellers who have gone through that country lit natural gas along the banks of the river and used it for camp purposes. A gentleman who was there boring for oil told me that he had used natural gas constantly, as it was escaping through natural openings in the ground.

Then there is salt. Let me quote again from the evidence given before the Senate Committee: " Near Fort Smith there is a salt mine which is probably the most beautiful and the most abundant in the universe. There is here a veritable mountain of salt. By digging a little in the earth, from six inches to a foot, rock salt can be found there."

Gold has also been discovered there; also copper. There is no question but that copper exists at some points in the Barren Lands. Bishop Clut, in his evidence before the Senate Committee, spoke of Indians coming into Fort Providence and having crosses made of copper. I do not think that any white man has found out exactly where that copper came from. At any rate, there is lots of copper.

There is also coal. In 1789, when Sir Alexander Mackenzie went down the Mackenzie river, he found that there was coal in the banks which was burning, and this extended for many miles along the river. That coal is burning yet.

Iron also exists in many parts of that country. Mr. Tyrrell, I think it was, described the country north of Lake Athabaska as being most promising from a mineral point of view. I cannot enlarge upon the subject of minerals, but I merely mention the fact of their existence.

I want to ask your attention for a minute or two upon a point about the mineral question in that country which has impressed me, but I do not know whether I can convey that impression or not. I want you to consider Dawson City, which is marked with a small red star on the map. I have here a clipping from the 'Manitoba Free Press' of twenty years ago, in which it says that miners had just discovered gold in the northwestern part of Canada up near Alaska. That was the first intimation that any gold was to be found there. I have the figures of the Geological Survey showing that over $123,000,000 of gold were taken out from the Klondike fields up to January 1st last, and it is well known that that amount is far within the mark. As a matter of fact, the output is a great deal more than that. So much for Dawson City.

Take Rossland, B. C. I lived in that city for two years, and I am somewhat familiar with the conditions. The townsite of Rossland was ungranted land of the Crown in the year 1894. The Le Roi mine is just on the edge of the townsite, and the total product of gold, silver and copper at Rossland up to the same date as I have given for Dawson was over $40,000,000.

Now just for a moment let me refer to Fernie, B. C. The coal deposits at Fernie were unknown twenty-five or thirty years ago, while to-day the coke required for smelting operations throughout the interior of British Columbia is furnished from Fernie. When I was in that country in 1896, they were importing coke for this purpose from Swansea in Wales. I got some figures from Dr. Haanel, Director of Mines, about the coal at Fernie, and from the figures which he gave me I make this calculation: there were 1,800,000 tons of coal mined in the year 1907. Taking that as a basis, it will take 12,222 years to exhaust the coal in that field at that annual production per year.

Another point farther east, in our own Province of Ontario, is Sudbury; the discovery of the copper and nickel mines of Sudbury was coincident with the construction of the Canadian Pacific Railway, and the discovery of Cobalt, is a matter of about five or six years. Now I think that when you reflect upon the fact that these discoveries have been made in a partially prospected portion of Canada, but only partially prospected, and consider that probably more than one-third of the total area of the Dominion has not been prospected at all, and that these discoveries have all been within the last twenty years, you will admit that it opens up great possibilities. We have the evidence from the staff of the Geological Survey as to the discoveries of the past, and there is every reason to expect that there will be equally great mineral discoveries in the Northwest in the future.

The timber resources of the country I have not got time to dilate upon, but they are known to be very great.

I just want to mention the water powers. There are beyond question water powers of enormous value in that country, and with the development of electricity it is hard to set a limit on the value which those water powers may have.

I am going to mention one more subject, and that is the fish wealth of the North. If there was no other source of wealth in that country I think it would be of tremendous importance to the people of Canada to be made aware of the value of the fisheries of that country. There are in every lake, river and stream enormous quantities of fish: whitefish, lake trout and jack fish in the clear waters, and sturgeon in many rivers, salmon in the rivers running into Hudson Bay and the Arctic Ocean, and the salmon known as the Inconnu in the Mackenzie river and in Great Slave Lake.

I have tried to compile figures that would impress upon you the value of the fisheries, but I do not know whether I have accomplished anything or not. With such meagre information as I had, I tried to make an estimate of the water area in that country. Every lake, river and stream probably is full of fish. West of the Nelson river and north of the settled area, I estimate there are about 75,000 square miles of water. There is a great deal more than that, because there are many smaller lakes that we have not got any information at all about. That is very nearly the same area as there is in Lakes Superior, Erie and Huron combined, but the Canadian portions of all the Great Lakes would not exceed about 33,000 square miles. There are two lakes, Great Slave Lake and Great Bear Lake, each of which is larger than Lake Erie, considerably larger.

The natural system of waterways in that country attracts one's attention. I have not got the figures exactly at hand, but I think it is in the neighborhood of 1,300 miles from Fort Smith to the mouth of the Mackenzie river, in which steamers drawing six feet can navigate at any time of the year when the river is open. Fourteen miles above Fort Smith you get into another system of waterways going up the Slave and up the Peace rivers, with falls not far from Vermilion. Above those falls you can go for 550 miles up the Peace river to the Rocky mountains, all navigable. Then there is the Athabaska river, or a considerable portion of it. So we have very much over 2,000 miles of navigable waterways in that country.

Now, gentlemen, there is a deduction that seems to follow from all these statements if they amount to anything at all. That deduction is, that it is time that we knew more about the country. I think it is time more knowledge was acquired, and I am going to ask you to consider for a few moments a condition somewhat similar to that which we have here in another part of Canada—I refer to New Ontario. Previous to about the year 1899, I think, it would be the opinion of anybody who knows anything of Ontario that the region north of the Canadian Pacific Railway line was of no value whatever for any purpose practically speaking. I had always heard it so spoken of myself, but without dwelling upon it, let me say that it was a country which did not promise to be ever of any great value. Some six or eight years ago an exploration of that country was undertaken. I believe that for departmental purposes New Ontario was considered to be the country lying north of the main line of the Canadian Pacific Railway. The country was divided into ten districts, and there were surveyors appointed who took charge of each district for exploration purposes. Attached to each party was a land examiner, a geologist and a timber expert. Well, I have been told—I went to some trouble to find out—that the cost of that exploration was $74,000. When the reports of these exploring parties were made up the Government were able to announce that there were 16,000,000 acres of clay lands in New Ontario suitable for settlement. There were nearly 300,000,000 cords of pulp wood discovered in New Ontario. Was not the building of the Temiskaming and Northern Railway a result of that exploration? The discovery of Cobalt was in consequence of the construction of that railway; and I believe the fact of there being 16,000,000 acres of clay land in New Ontario, which will be traversed from end to end by the Grand Trunk Pacific Railway, was an assurance to the people of Canada that there would be local traffic on the line and it would, therefore, be a much more certain enterprise than it otherwise would have been.

There have been 1,800,000 acres of land surveyed since that exploration took place as a result of it, and the Deputy Commissioner in Toronto in writing to me made a very remarkable statement. He said that in some of the townships it had been found that there was not one single acre of land which was not suitable for settlement, and, he added, " I think that is a record unique in any country."

Now I have just about finished, gentlemen, and I hope I am not wearying you. I told you at the outset that there were practically 7,000 miles of railway. There are the Canadian Northern, the Canadian Pacific and the Grand Trunk Pacific systems, and you will notice on the map not far west of Winnipeg three small lines, which represent the Hill lines, which have just entered into that country. I think there is no question that Mr. J. J. Hill would not undertake to enter that country to such an extent if he did not intend to remain there. Therefore, it is almost certain that the Hill system will spread over that country as well as the three other systems referred to. Now if you consider the railway situation there and bear in mind the facts which I gave a few minutes ago as to the result of exploration in New Ontario, have we not the right to expect if we can demonstrate beyond question by actual exploration that the north country is what I take it to be, that those railway systems will extend into it and occupy and possess it in the railway sense of the term? The Canadian Northern is at the Pas on the Saskatchewan, at Prince Albert, at Battleford, and at Edmonton. The Canadian Pacific Railway is at Edmonton. Surely the Grand Trunk Pacific Railway and Mr. Hill's system would not stop short of it if there was any traffic to be got. I think it is easily capable of demonstration that before long we shall see railway construction in that country which will open it up and lead to further discoveries.

I remember when we used to hear in the West, it was an expression used derisively about us from across the line and was used very frequently, that the Canadian Pacific Railway was " The Dominion on wheels," and it was often said that Canada consisted only of a fringe of settlement along the northern boundary of the United States. Well, gentlemen, when we consider that Fort Simpson is 900 miles north of the International boundary and that wheat has been successfully grown there under unfavorable conditions, I think that we are in a position to show that the Dominion has broadened considerably from what it was twenty years ago."

Mr. Young, in closing, pointed out how much it meant to the members of the Engineering Society of Toronto University and to the profession of Engineering in Canada that the development of the natural resources of this country of ours was up to the present time so small in comparison with the reasonable certainty of the future, and as a final word appealed to the young men of the Society to consider well if in any country there was a more magnificent heritage than is the possession of the Canadian people. He urged them also to remember always that such unequalled opportunities laid upon the people of Canada a tremendous burden of responsibility that they should adequately carry out to its fulfilment the magnificent destiny which appeared to have been marked out for them.

SHOULD FEDERAL AID BE GRANTED TO ASSIST TECHNICAL EDUCATION?

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The modern world needs technical education. "To make well and to sell cheap" is the working creed of the great nations. "To make well" means more to-day than it meant a hundred years ago. Knowledge has put the forces of nature into subjection. Science, mathematics, and art have transformed all industrial activities. They have made old trades more exact and scientific, as witness the trades of the wood worker, metal worker, textile worker, and engineer. They have created new high-grade trades—the trades of the art worker, chemist, electrician, and that vast army of tradesmen who minister to the comforts of our homes and leisure hours. While the trades demand more knowledge, the shop tends to teach less. The old apprenticeship system is disappearing. The machine replaces the man. All work becomes standardized and automatic. The workman, limited in functions and mechanical in attainments, quickly attains his full industrial stature and as quickly degenerates. Over every phase of modern industry is written large the demand "more knowledge" and side by side with it appears the response "less opportunity." Here lies the need of technical education.

What is the world's need is in a special sense Canada's need, and what is the need of the man at the bench or counter is in a special sense the need of the captain of industry or the consulting engineer. Canada's raw materials are widely distributed and difficult of access. Her motive power is unlimited, but remote from urban centres. Her problems of transportation are greater than those ever yet solved by six million people. And she is exposed to the competition of the greatest industrial nation of modern times. Here lies Canada's special need of the highly-trained expert.

But technical education is expensive. No two nations and no two educationists agree as to its form and content: it is still in the realm of experiment. Experiments are proverbially expensive. They consume material under conditions that are not commercial. They have to do with hordes of students whose fee-paying powers are limited, and with teaching plants as varied as the trades, and as unstable as machine shops.

Who will bear the expense ? In Europe the burden rests with varying stress upon the trade guilds, the manufacturers, the municipalities, and the State. Everywhere the State's proportion of the burden steadily appreciates. In America next to the municipalities and the State, the philanthropists are the fairy god-mothers of technical education. Here, too, the State assumes a steadily increasing proportion of the cost of maintenance.

It would be far from generous to belittle the splendid benefactions of such men as Sir William McDonald, but Canada's needs in this matter of technical education cannot be met by her philanthropists. Nor should the municipalities be expected to meet them. These needs are national, not local. In any case, the burden would be too great for the municipalities. It remains, then, for the State to take up the burden.

Now the State may mean the Province or the Dominion. The Province, let it be confessed, cannot do much. Its revenues are limited, and they are strained to the breaking point by recent subventions to elementary education and to instruction in agriculture. The Dominion, on the other hand, has buoyant revenues collected from the people of all the Provinces. It has a splendid asset in crown lands purchased at the expense of all the Provinces. Finally, it has a dominant interest in such national issues as commerce and industry.

But the Dominion has been cautious, not unreasonably cautious, perhaps, in recognizing its duty in these premises. Education, it has pointed out, is, in the term of the B.N.A. Act, a Provincial, not a Dominion interest. It is unwise to disturb the Constitution. Interferences with Provincial rights have not been happy in results. Federal aid to Education in one form would be a grave precedent as regards all other forms. And so the Federal publicist has been cautious !

Let us look at this caution from the other side. The United States government aids technical education in the various States, and does not find it difficult to separate one form of education from another. The Dominion government itself aids certain forms of technical education in the Provinces, and has not found grave difficulties in the precedent. Grants in aid of technical instruction would not be unhappy interferences with Provincial rights when all Provinces and all classes in all Provinces welcome those grants. Moreover, grants-in-aid need not involve interference with Provincial control. They do not involve interference with State control in the United States, or with Cantonal control in Switzerland. The Constitution should be sacred, but it must change with the centuries. Canada's Constitution has already been changed for interests scarcely as important as technical education.

But would Federal aid to technical education be a violation to the British North America Act and would it require a change in that Act ?

In the terms of the B. N. A. Act trade and industry are Federal interests. Technical instruction belongs to trade and industry. Is it not therefore a Federal interest? The Dominion maintains a splendid type of instruction in engineering in the Military College at Kingston and defends such technical instruction as attaching naturally to militia and defence, which is a Federal interest in the terms of the Constitution. It maintains experimental farms, dairy stations, and cold storage centres, with bulletins to instruct the people in the operations of these agencies, and defends this technical instruction as attaching naturally to agriculture, which in its larger phases is a Federal interest in the terms of the Constitution. It goes even further. In commercial agencies in the world's great trade centres, and in national expositions and world expositions, it aids or organizes magnificent agencies in the development of industrial intelligence —a form of technical education which attaches logically to trade and industry, and is a Federal interest. Surely it would not be altogether unnatural, or illogical, or illegal, to recognize all instruction in the arts and crafts as within the sphere of trade and industry, and to that extent a Federal interest.

Even if technical instruction were a thing apart, attaching itself to education proper and not to trade and industry, the Federal government could still aid it and be consistent with its own practices. It assists the Canadian Mining Institute, the Royal Society, the National Art Gallery, and the National Museum. It maintains several biological stations, schools of navigation on the inland lakes, and to some extent, the Department of Railway Engineering of McGill University. It organizes a Bureau of Standards, instructs the commercial classes in the metric system, and experiments in the electric treatment of Canadian ores. Through its grants to the Royal Canadian Academy it aids the art schools of the provinces. Would it be wholly inconsistent to subsidize the science and art of the technical schools?

Federal grants to technical education would find precedents in the practices of other lands. The authority of the Federal government in Germany is singularly circumscribed. The German states are practically autonomous and jealously so. Education attaches to each state. And yet out of its large ambitions for commercial supremacy the Federal government maintains an Imperial Physical and Technical Institute for standardization and research in the industries, and organizes navigation schools, shipbuilding schools and schools of naval engineering on the Baltic.

Decentralization of authority is the keynote of the Swiss Constitution. Differences in race, language, and creed have secured permanence for that keynote. In the terms of the Constitution education is transferred formally to the Cantonal governments and the Cantons are peculiarly sensitive as to the maintenance of their prerogatives. But they welcome Federal interest in industrial education, and Federal grants in aid of the trade and industry of the country. Thus it comes about that the Federal government maintains at Zurich one of the world's foremost colleges of Technology. It subsidizes the higher commercial colleges of the Cantons, and even many of the primary commercial schools. Quite recently, indeed, it has organized a schedule of grants for agricultural and industrial education of an elementary type, for schools of domestic economy, and for schools for the professional training of women.

But more interesting to us and more pertinent is the precedent set by the United States. State rights mean more to the average American than provincial rights mean to us. Education is a state right, and yet in the Morrill Act of 1862 the United States Congress granted the equivalent of 13,000,000 acres of land, valued at $10,000,000, to the various states in aid of state colleges for instruction in agriculture and the mechanical arts. In the Morrill Act of 1890 Congress added to this an annual grant to each state of $15,000 (which increased to $25,000 in ten years). Going even further, Congress makes a special annual grant to each state of $15,000 in behalf of an experimental and scientific station in agriculture. From all sources the Federal grant to the states in behalf of technical education now amounts to 41 per cent. of the total revenues of the technical colleges of the United States. In the presence of such examples need the Dominion hesitate?

Finally, above and beyond all statutes and precedents stands the great truth that the Federal government is sponsor for the commercial and industrial welfare of this country. In the performance of its duties in this regard it arbitrates trade disputes, organizes trade agencies, negotiates commercial treaties or establishes national tariffs. But arbitrations, agencies, treaties, and tariffs are altogether vain things if the Canadian workman or the Canadian engineer lacks industrial intelligence. To give industrial intelligence then is here the first and great duty of the Federal government. Can it perform this duty without cost?

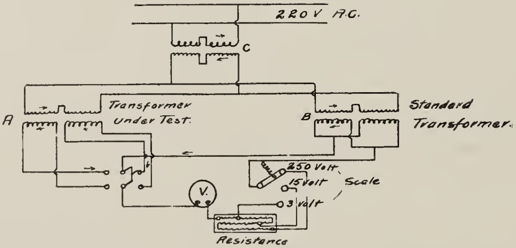
SOME NOTES ON TRANSFORMER TESTING.

E. M. WOOD, '06

It is not the intention of the writer to try to write a treatise on the subject of Transformer Testing, but to offer a few practical notes based on experience on certain methods, which do not come within the scope of the instruction given in the School.

The purpose of commercial testing is twofold: first to make sure that the construction of the piece of apparatus is mechanically and electrically correct, and secondly to give the engineering department data to check the correctness of their designs, constants, etc. Tests made for the latter purpose are usually omitted on apparatus that is "standard", that is on apparatus of which a considerable number of units have been built to the same specifications. The first few machines built under new specifications should have complete tests.

The first class of transformers whose testing we will discuss is the small "lighting" transformer, usually of less than 100 k.w. capacity. Since these are turned out in comparatively large numbers in standard sizes, voltages, etc., it is essential that the tests on these should be sufficient and, at the same time, not take too much time. The standard tests are for insulation, polarity, conversion or voltage ratio, losses, regulation and heating. The insulation tests are of two sorts: the high voltage test to detect grounds, and the short circuit test. This latter test consists in applying double or triple normal voltage to the secondary winding of the transformer. This gives double or triple the normal voltage between turns in the winding and causes a short circuit and burn out if the insulation between turns is weak. To avoid large exciting currents the highest available frequency is used. (In all testing departments the low-tension side is called the "secondary" and the high tension side the "primary").



The conversion and polarity tests check the proper winding and assembly of the coils. A rather neat scheme for taking polarity and conversion at once on a transformer of standard voltages is shown in Fig. 1.

The transformer under test A and a transformer B of the same voltages and ratio, whose ratio has been carefully taken by voltmeters, are connected in parallel on the primary side, and both excited from a suitable transformer C as shown. Then each secondary coil of A is connected in turn, as shown, in series with the standard secondary and a voltmeter, so that if the polarity is right, the units of the two coils oppose each other. If conversion and polarity are right there will be no voltmeter reading. The voltmeter should be provided with taps in its resistance so as to give, for example, 250, 15, and 3 volt scales. The 3 volt scale is necessary to show whether or not the conversion is exactly correct, but when first connected the voltmeter switch should be on the 250 volt connection (i.e., if the transformers have about the standard 110 volt secondary coils), so that the meter will not be damaged if the polarity happens to be wrong. Of course a wrong polarity on a coil will show by adding the units instead of substracting, and the meter will read 220 instead of zero.

Core losses and copper losses are taken by wattmeter by well-known methods. Frequency should be correct and the wave shape of impressed voltage sinnsoidal, or else the wave shape and the relative core losses due to this shape and to the sinnsoidal wave, should be known. Since the readings on the wattmeter are small, the meters should be connected so that each meter reads exactly what it is intended to read; errors due to power taken by other meters being generally not negligible. Proper connections are shown in Figs. 2 and 3.

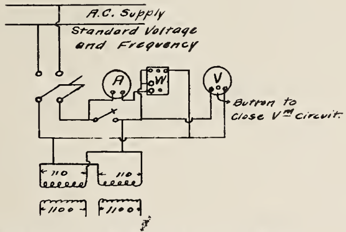


Figure 2— Core Loss Connections.

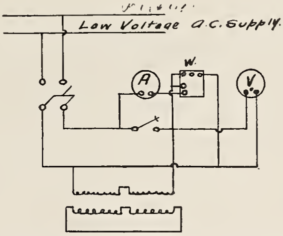


Figure 3. — Impedance Connections.

For core loss, the voltage should be set, then the voltmeter circuit opened and watts read, then wattmeter pressure circuit opened and exciting current read. In the impedance copper loss test, the current is set with all pressure coils open, then impedance volts and then copper loss watts read separately. All current coils should be protected by short circuiting switches. This is a precaution that should be taken in all testing work.

The heating test usually consists in running the transformers in pairs under core loss and a small overload copper loss for a couple of hours. The method will be considered in detail later. This test is merely a load run to show up weak spots. The tests for heating are made when the type is under development, and not necessary on the article after it has become standard.

Practically the same tests are applied to large power transformers. However, as these are not so well standardized as the smaller types, special methods have to be employed.

Conversion is best taken after the core has been built up, but before the transformer has been completely assembled, because with the large "slab" wound transformers with many coils it is easy to get coils interchanged, or wrong way around, and the transformer has to be torn down. The best procedure in taking conversion is to first make out from the winding specifications a diagrammatic scheme of the windings, showing the number of turns, the location of taps, ends of coils, etc. Then a suitable number of turns in a coil is taken as a primary, a voltage of so many (say 2 or 10 or whatever is convenient) volts per turn is impressed and voltages on the other sections read. The volts per turn for each section should be the same. The laying out of the scheme for taking conversion requires some ingenuity and a knowledge of the meters, potential transformers, etc., available. Voltmeters for this purpose should be kept carefully calibrated.

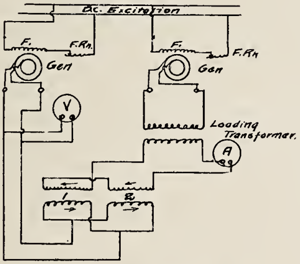
Core loss is taken in much the same way as in case of small transformers. The method or order of connecting the meters in circuit is scarcely so important as meter losses are negligible. Wave form of impressed voltage is as important as before, if comparison between different transformers is desired. It is customary in some places to take an oscillogram of applied voltage under some standard conditions, for example, normal voltage on transformer. This is filed with the test report for reference.

Any available part of the winding with sufficient number of turns to keep within reasonable limits the magnetizing current necessary to produce the normal voltage core flux, may be used as an exciting coil, and to it should be applied its proportion of the normal working voltage. This will produce normal working flux in the core and normal core loss. The coil should be so chosen, if possible, that its voltage is less than 3,000 volts, as below that voltage it is safe to use resistance multipliers in the pressure circuit of the wattmeter. These are more satisfactory than the potential transformer, as the latter does not have its primary and secondary voltages in exact opposition in phase. This causes the wattmeter to read too low.

Copper loss and short circuit impedance volts are taken by the usual short circuit test. Resistance of primary and secondary windings with connections for the short circuit test should be found, and the connected and observed total copper loss should check very closely.

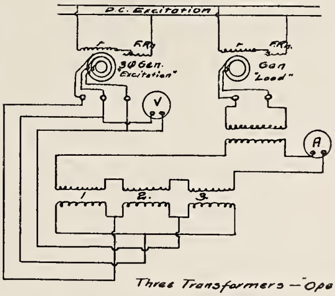
Resistance may be taken by D.C. drop of potential method, or by Wheatstone Bridge. In taking resistance by bridge, it is advisable to keep the "battery key" closed until the reading is completed, to avoid the great self-inductive "kick" when it is opened. Incidentally, this necessitates the use of a good battery in connection with the bridge. For the P. D. method a storage battery or D.C. exciter may be used, with suitable rhostats in series. The cores of large transformers seem to possess considerable magnetic inertia, so in order to avoid disturbances and variations of the voltmeter readings, as the magnetism in the core is gradually built up by the effect of the direct current in the windings, it is well to apply current up to about twice the value it is intended to use, hold at that value about a minute, then reduce the current to the required value, and close the voltmeter circuit. If the voltmeter needle is steady and does not "creep" towards lower readings, the meter readings may be taken. In order to damp out variations in D.C. current, the winding that is not having its resistance measured may be short circuited on itself. Connections for voltmeter should be made nearer the winding than the connection points of current leads and transformer leads. This arrangement insures against including the contact resistance of the leads in the resistance of the transformer coil.

Heating tests on power transformers are necessarily made with more care than on lighting types. The iron and copper losses are supplied as follows: The transformers are connected as shown in the diagrams 4 and 5, "bucking" if two of a kind are available, and "open delta" on the primary side if three are under test.



Two Transformers — "Bucking."

Figure 4. Heating Test Connections



Three Transformers — "Open Δ

Figure 5. — Heating Test Connections

Take the case where two are under test. The core losses are supplied by exciting the two secondaries in parallel, up to normal working voltage, by a suitable generator, with or without an auxiliary transformer. The impressed voltage is adjusted by varying the field of the generator. The secondaries should be connected so that all their windings are in circuit. The primaries are connected in series, as shown in the diagram No. 4. This causes the primary E.M.F.'s to be opposing each other or "bucking," and the voltage across the two is zero. If an A.C. voltage at any convenient frequency be applied here equal to the sum of the "impedance" voltages of the two transformers at that frequency, full load amperes will be forced through primary and secondary windings of both transformers, for, as will be seen by the diagram, the secondary connections form a short circuited secondary to this primary "impedance" voltage, as in the impedance test. This current then supplies the copper loss, and does not unbalance the core loss seriously. This "load" current may be supplied by a separate generator or by the "exciting" generator, but should pass through a transformer with strong insulation between primary and secondary, even if the required ratio of transformation is 1 to 1. This is necessary because the "load" wiring may have a potential against ground equal to the high tension voltage of the transformer under test, and it is easier to insulate against this in a transformer than in a generator. If three transformers are to be tested they are connected as shown in Fig. 5. The secondaries are excited in △ from a three-phase generator and the primaries are connected in open delta as indicated, and the load current introduced into the open "corner."

Resistances and temperature should be taken before starting the heat test. The transformers may be put on overload copper loss until the oil temperature shows that heating is about to final value, then the losses are set at normal value and the cooling medium (usually water) introduced, and the amount adjusted according to guarantees. When it is reasonably certain that this is correct a resistance may be taken, and the conditions maintained another hour or so, followed by a final hot resistance. This should be the same as the last one. For calculating temperature rise by resistance, it is best to base calculations on change of primary resistance. "Hot" resistances should, if possible, be taken with same meters and same current settings as the "cold" resistances.

Short approximate formulae are in use for calculation of temperature rise by resistance. One of these in use is as follows:

$$\text{Rise by Res. in } C^\circ = \frac{\text{Res. hot} - \text{Res. cold}}{.0041 \times \text{Res. cold}}$$

After a transformer has slightly cooled down from the heating test, it should be given the "high voltage" ground test. This consists in applying from two to three times normal working voltage between primary and grounded (to case and core) secondary, and between secondary and grounded primary.

The testing transformer should be excited from a generator of suitable voltage, so that the generator voltage will be somewhere near its normal value when the high tension testing voltage is correct. This allows the generator to give its proper wave form. This should be as nearly as possible a sine wave. The voltage should be adjusted by means of the generator field rheostats, and never by rheostats in series with the low tension side of the testing transformer, as their presence there changes the wave shape. Testing voltages may be measured by spark gap, by conversion, or by a combination of the two. If the transformer under test be insulated from ground by being set on an insulating platform, the middle point of the testing transformer's high tension winding may be grounded. A section of this winding next to the ground may safely have a tap brought out, suitable for voltmeter readings, containing say $\frac{1}{1000}$ of the high tension turns between the tap and the ground. This gives a measure of the high tension voltage. The voltmeter readings should be checked by spark gap under *actual conditions* of test.

The procedure in applying high voltage test to a large transformer, then, is as follows: The testing transformer is connected to the transformer under test, one terminal to primary winding, the other to secondary winding and case. Across these leads is connected the needle gap. Often to keep down current surging when the gap breaks, water resistances are connected in series with the spark gap. These reduce the effective spark gap length by an amount that must be found experimentally. If the testing voltage is, say, 100,000 volts or less, the gap is set at the required length according to A.I.E.E. curve, for fresh needle points. With transformer connected in circuit, the voltage is increased gradually by generator field control and the voltmeter reading carefully watched until the gap first snaps. Voltmeter reading before the "jump" is carefully noted, and the field lowered to zero. Then the gap is opened wide and the voltage gradually brought up till the same voltmeter reading is obtained, held one minute and gradually lowered to zero. It should take at least three minutes to bring voltage from zero to required testing voltage. Sudden changes of voltage should be strictly avoided. For voltage of over 100,000, the procedure is slightly different. The spark gap may be set at $\frac{2}{3}$ testing voltage. Carefully break down this gap, noting voltmeter reading. Having separated the needles, bring up the voltage to $\frac{3}{2}$ the former reading, corrected for calibration of the meter.

After a transformer has stood insulation test it should be run under normal voltage for a sufficient time to make it evident that it has suffered no damage from the test.

MODERN FINE GRINDING MACHINERY

E. V. NEELANDS, '00

The most essential feature in the successful treatment of ores amenable to concentration, is that a stage of crushing shall be reached at which the particles of valuable mineral are free from the associated gangue, in order to allow the millman to take full advantage of any distinguishing feature of either to effect the desired separation. Whatever be the preliminary process, excepting a few special cases, the resulting pulp must be reduced to a very fine slime to fill this condition. That this fact has been fully realized is evinced by innumerable patents for fine grinding machinery, much of which is now in more or less successful operation. Prominent among these are Chili & Huntington mills, stamps and narrow-faced, high speed rolls, but all open to many objections when grinding finer than to 40 mesh, at which size the tailings from most plants would contain values which could not be recovered.

These objections may be briefly summed up: In the case of Chili & Huntington mills the wear is very great, the renewals costly and much attention is required. In this connection the great importance of selecting mill machinery which practically cannot get out of order, is to be emphasized, because the modern mill is a continuous series of machines, each adjusted to take a definite product from the one preceding, with the result that the failure of even a minor part may cause many hours' delay. Rolls are open to the same objections, their adjustment for fine crushing being very difficult to maintain, in addition to the fact that the product must be continually returned in order to reduce to any definite mesh. Stamps while very efficacious for many kinds of work, are inefficient when reducing to slimes, the same blow being delivered and the same power consumed in crushing 2-inch cubes as in reducing ¼-inch material. The wearing surface of both dies and shoes is always sufficiently uneven to allow the escape of the greater part of the partially crushed ore and to throw the whole force of the blow on a comparatively small percentage of it, reducing much material to the impalpable slimes so difficult to handle by the ordinary gravity methods.

The increasing demand for an efficient machine for this work eventually produced the tube mill, which consists of a sheet-iron drum with cast steel ends. It is lined throughout with hard steel liners or cut flint bricks set with neat cement and contains one or more tons of flint pebbles. The drum is rotated by means of a pulley and shaft and tooth-wheeled gearing and in the common forms is supported at each end by hollow trunions which serve as bearings as well as passages for a continuous flow of feed and product. The ore, crushed to from 8 to 20 mesh, enters the mill by a suitable contrivance, is triturated by the pebbles in contact with each other and the lining and as it becomes sufficiently reduced to be held in suspension by the agitation of the water, flows through a grating, from the discharge end.

The speed of rotation has been a matter of some discussion, but the best practice, especially on the coarser grades of feed is that the speed should be slightly lower than that at which the mass of pebbles would be carried completely around the drum by centrifugal action. The pebbles should rise to a point about one foot lower than the top of the drum and then drop violently. This action may be observed in some machines by removing the hood on the discharge end and holding an incandescent lamp in the hollow trunion. In a mill 6 feet in diameter, it takes place at 21 R.P.M. in the absence of water; if water is used at 27 R.P.M. The peculiar feed and discharge arrangement of the Abbe tube mill have resulted in a very different conclusion by its manufacturers. These arrangements permit the mill to be used when practically filled with pebbles, the action being simply grinding without impact, but giving an enormous number of contacts per revolution. As will be readily observed, this limits the size of feed to a mesh at which comminution can occur by the mere friction of the pebbles. This mill is claimed to be efficient on 30 mesh material (*a*). The opinion of the writer is that the former practice is the better as it allows the product of rolls to be fed directly to the mill, eliminating any intermediate crushing. (See mesh tests, page 271.)

One of the most important features of the tube mill is that is it absolutely automatic and continuous. This great advantage over other forms of comminutors will be at once recognized by the practical millman. There are no nuts to get loose, no adjustments requiring shut-downs and no tires or dies to be trued up. In the mill under the writer's direction, the only costs for a year's operation have been for pebbles (two tons, original charge not included) and for lubrication. Linings have to be renewed in from four months to a year, but the recent introduction of automatic linings bids fair to largely eliminate this expense and loss of time. These linings are of various forms and depend on the tendency of pebbles to wedge themselves in any crevice. Ribs of iron are placed close together in the drum forming recesses into which the pebbles are driven by their own action (*b*).

These machines have found special favor on the Rand and are now used to a large extent in Mexico and the United States. In the majority of cases they are used for reducing the tailings from stamps for treatment by cyanide. At the present time there are sixty at work at Johannesburg alone (*a*). Opinions on the Rand varied for some time as to the question of their advantage

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(*a*) **Engineering and Mining Journal, advertisement.**

(*b*) **" " " Vol. 84, No. 21, page 986," Tube Mill Lining, H. W. Hardinge** over an improved form of the grinding pan (*b*), but the latest advices are in favor of the tube mill (*c*). The disadvantages are: (1) Heavy initial cost, especially in places not reached by railroad; (2) inaccessibility; and (3) inflexibility of the unit. The latter is the chief drawback; if one mill is slightly overloaded, it is necessary to provide another with the result that their combined capacity is greatly in excess of the work to be done while the power and other costs doubled. In a case where the product is to be treated on tables it is also very difficult to control the size of product, which in the case of a light feed, has a tendency to become an absolute slime. As the drum should be absolutely tight, access to the interior can only be had by means of a manhole cut in the shell; this hole must be firmly closed as a leakage may cause a serious loss in addition to a rapid destruction of the gearing if it is accessible to the pulp.

A consideration of the limitations of the tube mill resulted in the introduction (November, 1907) of an improved and modified form of pebble comminutor, the Hardinge Conical Mill. Except in a few minor details this machine differs from the tube mill in shape only, the drum or tube of the latter being replaced by a form, which may be described as a short cylinder, having each end rigidly attached to a cone. The apexes of the cones are hollow trunions, which act as bearings and as passages for the pulp as in the parent machine. (See cut front page Engineering and Mining Journal, Nov. 23, 1907.) A very good model of this mill may be made by taking two large glass laboratory funnels and attaching them together by means of electric tape. If this model is partially filled with small pebbles, ¾-inch diameter to 8 mesh, and slowly revolved in a horizontal position, the action of the mill can be seen and appreciated. After a few revolutions it will be seen that the larger pebbles have displaced the smaller and occupy solely the zone of the greatest speed at the junction of the two cones; the pebbles are perfectly sized in order of their weights, from the greatest at the centre, extending up the slope to the smallest towards the ends. This action as has been proved by actual practice takes place in the working machines.

The result of this action will be readily observed: The ore enters through the trunion and spreads out as it flows down the incline; the heavier particles find their way to the centre at once where they are subjected to the heavy blows of the large pebbles and as they are reduced, work up the opposite incline, still under the action of proportionately smaller pebbles, until they are sufficiently reduced to flow from the discharge end. This is apparently an ideal crushing arrangement, the ore particles arranging themselves so that each is subjected to a blow suited

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(*a*) Tube Mills on the Rand, Mining and Sc. Press, Jan. 4th, 1908.

(*b*) Denny on Gold Milling Equipment, Pro. Inst. Civil Eng. Vol. CLXVI, Nov., 1906.

(*c*) Progress on Treatment of Gold Ores, Alfred James, Mining and Sc. Press, Jan. 4th, 1908.

to its size, and passing when broken to lighter and more numerous blows, and when sufficient reduction has taken place, being at once removed from further grinding action.

This sizing action of the mill is under perfect control within wide limits by the use of an elevating gear, by which the discharge end is raised or lowered a few inches. If lowered the slope of the incline is lessened and the ore discharges in a less finely ground condition, with almost no slimes, and if raised it can be ground to practically any degree of fineness. In this way the mill can be made grind to a definite mesh, with a precision that cannot be approached by any other machine.

An important consideration is the saving in power of the conical over the drum form of mill. It will be at once noted that in the latter form the whole mass of pebbles is lifted practically the whole height of the machine, most of this work being unnecessary and reducing beyond the desired point, whereas in the former only part of the mass is raised fully to work on the coarse material and the remainder only partially to reduce the finer sizes.

By the introduction of balls or pebbles up to five or more inches in diameter for work on the coarse feed, it has been found possible to make this mill handle feed up to ½-inch mesh, a very great advantage over the tube mill, as the latter is practically limited to sizes smaller than 20 mesh and if fed with coarse sizes quickly "mucks up," owing to the fact that the small pebbles used cannot crack the ore particles and can only reduce them by attrition. (See mesh, page 272.)

Appended are the results of sizing tests on the various machines alluded to:

Abbe Tube Mill working on feed stamped through 20 mesh, 18 R.P.M. charged with 5 tons of pebbles:—

Feed.	
On 30 mesh ...	2.6 p.c.
" 40 " ...	4.4 "
" 60 " ...	14.8 "
" 80 " ...	18.2 "
" 100 " ...	15.6 "
Thro' 100 mesh.	41.2 "
	100.8

Product.	
On 60 mesh ...	4.2 p.c.
" 80 " ...	9.4 "
" 100 " ...	10.5 "
Thro' 100 mesh.	75.7 "
	99.8

Prosser Tube Mill working on ball mill product through 8 mesh, 26 R.P.M., charged with 2 tons pebbles, producing 2.5 tons per hour:—

Feed.		Product.	
On 10 mesh ...	5.7 p.c.	On 60 mesh ...	.6 p.c.
“ 20 “ ...	40.2 “	“ 80 “ ...	4.6 “
“ 40 “ ...	19.0 “	“ 100 “ ...	14.7 “
“ 60 “ ...	7.0 “	Thro’ 100 mesh.	79.8 “
“ 80 “ ...	6.2 “		
“ 100 “ ...	10.4 “		98.7
Thro’ 100 mesh.	12.0 “		
	100.6		

German Tube Mill working on feed stamped through 25 mesh, charged with 5.5 tons of pebbles, consuming 48 H.P. and producing 4 tons per hour:—

Feed.		Product.	
On 40 mesh ...	1.5 p.c.	On 60 mesh ...	.5 p.c.
“ 60 “ ...	13.5 “	“ 80 “ ...	1.5 “
“ 80 “ ...	17.0 “	“ 100 “ ...	2.0 “
“ 100 “ ...	17.5 “	Thro’ 100 mesh.	96.5 “
Thro’ 100 mesh.	58.0 “		100.5
	98.5		

Hardinge Conical Mill, working on roll product, charged with one ton of pebbles, consuming 15 H.P. and producing over 3 tons per hour:—

Feed.		Product.	
On 10 mesh ...	25.3 p.c.	On 60 mesh ...	1.4 p.c.
“ 20 “ ...	38.2 “	“ 80 “ ...	5.5 “
“ 40 “ ...	12.2 “	“ 100 “ ...	2.5 “
“ 60 “ ...	6.6 “	Thro’ 100 mesh.	90.8 “
“ 80 “ ...	5.5 “		
“ 100 “ ...	2.3 “		100.2
Thro’ 100 mesh.	9.5 “		
	99.6		

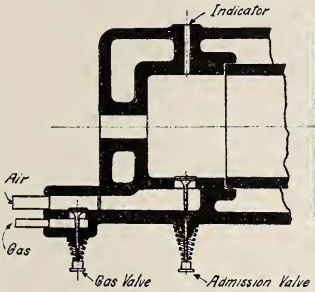
THE EXPERIMENTAL GAS ENGINE IN THE THERMODYNAMIC LABORATORY, UNIVERSITY OF TORONTO

W. W. GRAY, '04.

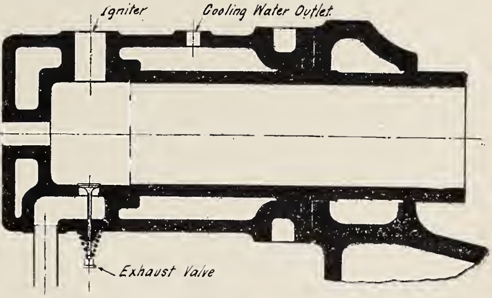
Demonstrator in Thermodynamics.

This engine was built by Fielding and Platt, Gloucester, England, and was installed in the laboratory in 1906. It is a single cylinder, single acting, horizontal engine, operating on the Otto cycle, and is rated at 9 B.H.P. at 240 R.P.M.

Fig. 1 is a horizontal section through the cylinder, showing gas and admission valves. These valves are of the common mitre type. They are held down on their seats by springs, and are operated through levers by cams on a side shaft, this shaft being driven by spiral gear from the crank shaft at half the speed of the latter. Fig. 2 is a vertical section through the cylinder. The exhaust valve is of the same construction as the gas and admission valves, and, like them, is driven by a cam on the side shaft. The springs on all the valves are adjustable, and the valve stems are fitted with adjusting heads, so that the times of opening and closing of any port are under complete control.



Horizontal Section through Cylinder.
Fig. I



Vertical Section through Cylinder.
Fig. II

The cycle of the engine is complete in four strokes of the piston. During the suction stroke a mixture of gas and air is drawn into the cylinder, the admission port being open throughout the whole stroke, and the gas port during just the middle part of the stroke. The mixture is compressed during the next stroke into the clearance space. At the end of this compression stroke the mixture is caused to explode, the pressure rising almost instantly to its maximum. Expansion takes place during the third stroke, the piston being forced forward. The exhaust port is open during the fourth stroke, and the spent gases are expelled from the cylinder. This exhaust stroke completes the cycle.

The governor is of the rotary ball type, and is driven by bevel gear from the side shaft. The engine is governed on the "hit-and-miss" principle, the governor acting on the gas valve. The gas valve is operated by a cam and lever, but indirectly through a block controlled by the governor. Should the speed require it, the governor allows this block to remain between the valve stem head and the cam lever, and the lever hits the block, and the valve is made to open the port every time. Should the speed rise above the normal the governor lifts the block, the cam lever misses the valve stem head, and nothing but air is drawn into the cylinder, the governor is so arranged that the engine may be run at any speed from 125 to 300 R.P.M., adjustment may be made while the engine is in operation.

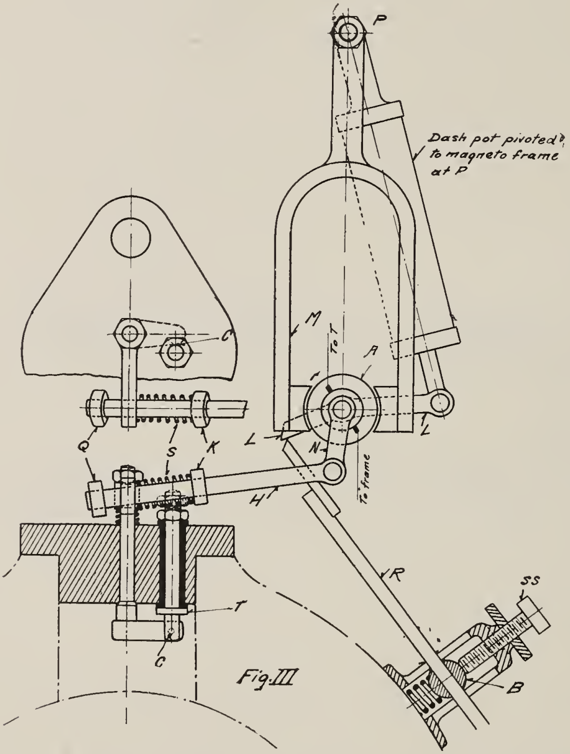


Fig. III

Three methods of ignition may be used on the engine: the hot tube, the jump spark, and the "make-and-break." Of these the most satisfactory is the "make-and-break." This method may be understood by referring to Fig. 3. *M* is a magneto mounted on a bracket on the cylinder. *LL* is keyed to the shaft of the shuttle wound armature *A*. *N* is a crank keyed to the other end of the shaft. The rod *R*, driven by an eccentric on the side shaft, engaging with *LL*, rotates the armature in the same shown by the arrow. At the same time the collar *K* on the rod *H* compresses the spring *S* against the crank *E*, and contact is made at *C*. When the end of *R* slips off the end of *LL*, the armature is jerked back by the dash-pot and a current is generated at the same time that the rod *H* is brought back and the collar *Q* strikes *E*, and contact at *C* is broken. This produces a strong spark, one terminal of the magneto being connected to *T*, an insulated plug, and the other to the engine at a convenient point. *SS* is a set screw by which the spark may be set to occur at any desired time. The ball *B* acts as a guide to the rod *R*, and its position fixes the time when *R* will disengage from *LL*. The spring keeps the ball against the set screw, and by turning the screw in or out the spark may be made earlier or later. This igniting device is in common use on European engines, and is most satisfactory. It seldom fails, and the spark is under complete control, and may be set while the engine is running.

The engine may be converted into an oil engine by disconnecting the gas gear and attaching a vaporiser and accompanying fittings. In this case the governor acts on both the vapor valve and the oil pump, and the charge ignites on compression without the use of the spark.

The accompanying table contains the results of a series of tests recently made on the engine. Indicator diagrams were taken at intervals during some of the tests, and the indicated horse power calculated. A Crosby special gas engine indicator was used with a 200 spring. This spring was too strong to allow the exhaust and suction lines to appear on the diagrams. A 10 spring was put in the indicator and diagrams taken, from which the loss of mean effective pressure due to exhaust and suction was found to be 2.5 pounds per square inch. This loss was taken into account in calculating the *I.H.P.* The brake horse power was measured by a simple friction brake on an internally water-cooled pulley. The mechanical efficiency, expressed as a percentage, was obtained thus:—$\frac{B.H.P.}{I.H.P.} \times 100$.

The gas consumed during the tests was measured by a service meter of the Consumers' Gas Company, calibrated under Government inspection. The ratio, volume of air to volume of gas, was determined by the following method: The total volume of mixture drawn into the cylinder per minute is piston displacement multiplied by the number of strokes of gas valve per minute. The volume of gas drawn into the cylinder

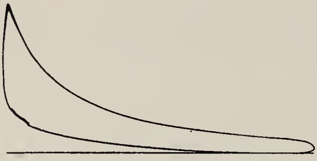


Fig 1

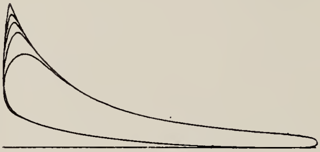


Fig 2

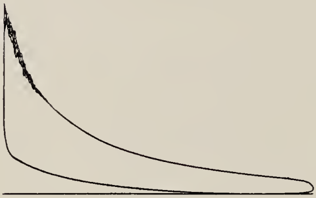


Fig. 3

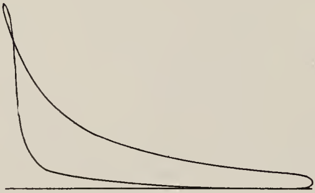


Fig. 4

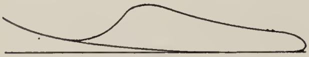


Fig 5

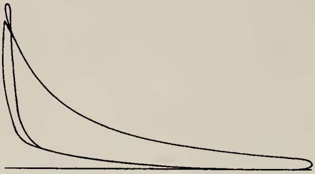


Fig. 6

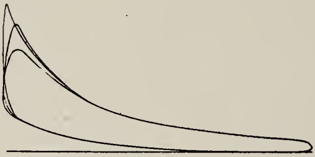


Fig. 7

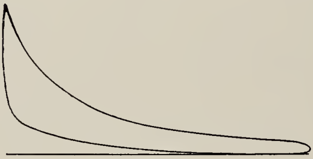


Fig. 8

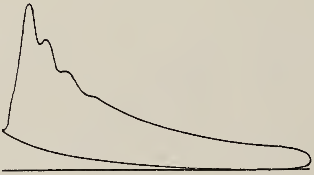


Fig. 9

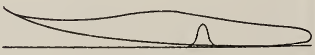


Fig 10

per minute was measured by the meter. The difference between the two volumes is the volume of air per minute.

The heating value of the gas is the higher heating value as determined by a Junker's gas calorimeter.

The results, *B.T.U.* per minute per *B.H.P.*, were determined thus, taking test No. 1 as an example:—*B.T.U.* per minute per $B.H.P. = \frac{19.1 \times 620}{60} = 197.$

The heat efficiencies were determined as follows, again taking test No. 1 as an example:—Heat efficiency $= \frac{33000 \times 100}{197 \times 778} = 216\%$

Examples of indicator diagrams taken from the engine are shown in the accompanying plate. Fig. 1 shows a diagram made by thirty consecutive tracings of the pencil. This shows a mixture as nearly perfect as can be obtained. The next diagram was taken with too little gas in the mixture. Fig. 3 shows the effect of too much gas. Early ignition produces a diagram as shown in Fig. 4, while late ignition gives a diagram such as Figs. 5 and 10. In Fig. 10 is shown a "back-fire," due to late ignition. Combustion is not complete before exhaust, and the unburned gas explodes in the exhaust pipe during the exhaust stroke. Fig. 6 shows two diagrams taken with the same spark position for two speeds. The diagram with the loop was taken with engine running at 195 *R.P.M.* The same spark position gives a good diagram for a higher speed, 220 *R.P.M.* This explains why the spark should be retarded when one is starting a gas engine. Figs. 7 and 8 were traced from diagrams taken when the hot tube was being used to fire the charge, No. 7 having taken engine under half load, No. 8 engine under full load. Fig. 9 illustrates a condition under which a gas engine will pound even though spark be late. In this case too much

Tests on Fielding and Platt Gas Engine, University of Toronto—Faculty of Applied Science.

Dia. of Cylinder—7.0 ins. Stroke—13.94 ins.
Clearance—24% of piston displacement.
Compression—90 pds. per sq. in. gauge.
Toronto illuminating gas—Electric ignition.

No. of Test	R.P.M.	Power		Mech. Eff'y.	Cu.ft.Gas per hr. per B.H.P.	Ratio Air/Gas	B.T.U. per cu.ft. Gas	B.T.U. per min. per B.H.P.	Heat Eff'y per B.H.P.
		I.H.P.	B.H.P.						
1	193	9.8	8.64	88.1	19.1	9.3	620	197	21.6
2	192	10.02	8.59	85.7	18.3	9.9	"	189	22.4
3	193	10.15	8.64	85.3	19.7	9.7	"	204	20.8
4	192	——	7.85	——	19.9	9.8	"	206	20.6
5	194	——	7.18	——	20.8	10.2	"	215	19.3
6	221	——	9.38	——	19.7	——	"	204	20.8
7	221	11.1	9.38	84.5	18.9	——	"	195	21.7
8	218	——	9.27	——	19.9	——	"	206	20.6
9	219	——	9.29	——	18.8	——	"	194	21.9
10	219	——	9.29	——	19.1	——	"	197	21.6
11	212	8.8	7.44	845	31.1	6.0	"	321	19.2

gas was supplied to the engine and a sharp knock was the result.

In all the tests excepting No. 11, the gas throttle was set by means of the indicator, so that a diagram such as Fig. 1 was obtained. The pencil was allowed to run over the diagram in some cases as often as fifty times, yet so nearly perfect was combustion that the diagram appeared as a single tracing. The condition for maximum efficiency may be thus obtained. In test No. 11 the indicator was not used to set the gas throttle; the mixture contained too much gas, and consequently there is a high gas consumption per *B.H.P.* and a low efficiency.

SOME NOTES ON THE MANUFACTURE OF STEEL RAILS, HAVING SPECIAL REFERENCE TO THE EDGAR THOMSON PLANT, PITTSBURG

J. ST. LAWRENCE, '08.

To arrive at the finished product there are two fundamental processes. First, the reduction of the ore in the blast furnaces, and secondly, the conversion of the molten iron into steel.

The purpose of the following paper is to outline this latter process.

The blast furnace plant consists of eleven furnaces of the most modern type, the output of each being about 500 tons per twenty-four hours.

The molten iron is tapped from the furnaces at intervals of four hours, and run into hot metal cars; these cars have a capacity of about thirty tons and are so constructed that the ladle may be caused to tip and unload contents by the turning of a worm shaft.

When filled from the furnace the cars are coupled to a locomotive and drawn over to the mixers. Opposite the intake hole the car is stopped and its contents poured into mixer.

These mixers are rectangular steel enclosures, lined with fire brick and balanced on trunions. They have a capacity of about 200 tons and this tipping mechanism is controlled by hydraulic power.

The mixers serve a two-fold purpose; they provide a means of supplying to the Bessemer converters a metal of uniform quality, and they also serve as a store for the molten metal. during a temporary break-down at the converter plant. The mixers are so located that a track runs above and below their level, the upper track being for the purpose of conveying the metal from furnace to mixer, and the lower track to take metal from mixer to converter plant. Situated thus, "gravity" aids in removing metal from car on upper track to mixer, and by tipping mixer on trunion the same force aids in filling car on lower track.

After the metal has been in the mixers from four to six hours it is poured into cars placed on the lower track and sent to the

Bessemer converter plant. Here is where the steel-making process really begins. The converters, four in number, are somewhat pear-shaped; sheeted with ½″ steel plate and lined with silicious rock and fire clay.

The converters are balanced on trunions, one of which is hollow and through this hollow trunion the blast is blown. From here it is piped to the bottom and admitted up through the tuyeres. Owing to the fact that the lining of the bottoms wears out much faster than the lining of the sides, the converters are so constructed that the bottoms are interchangeable and may be replaced with little labor. These bottoms are made of refractory brick or of rammed plastic material about two feet thick, steel encased. In this bottom the tuyeres are embedded in such a manner that the air holes are vertical. The tuyeres are made of circular brick, two feet long and six inches in diameter. Throughout the length there are about a dozen round holes, three-eighths of an inch in diameter; through these holes the blast is blown.

When the bottoms are newly "baked," these tuyere brick just come flush with upper surface. The blast necessary is supplied by Allis-Chalmers blowing engines, delivering it at a pressure of from twenty to twenty-three pounds per square inch. The process here employed is the "acid," and as no phosphorus is eliminated, this element must be kept low in the iron used. Such a grade of ore is used that this element does not exceed one-tenth of one per cent.

Sulphur, if present to any extent, is another element that produces undesirable effects in the rail, and in the iron from the furnaces this is kept low, seldom running above one-quarter of one per cent. By careful handling of the blast furnace this may be kept as low as two one-hundredths of one per cent. The molten iron also contains about three per cent. C. and from one to two per cent. Si. The presence of these two elements makes possible the manufacture of steel by this process. The iron also contains some manganese, but the heat evolved by the oxidization of this element is much less than that evolved by the former two, and so, in this connection, is of less importance.

TO CHARGE THE CONVERTER

The hot metal car is drawn up on the elevated track which runs parallel to the row of converters, the car is stopped oposite to the converter to be charged which has been tipped over into horizontal position to "receive." By a similar means to that employed at the mixers, the ladle of car is made to tip, delivering its contents to the converter.

The converter is now nearly in a horizontal position with the molten metal lying in the "belly" of the vessel. The blast is now turned on and the converter brought to a vertical position; the oxidization of the elements present has now commenced. To complete this process usually requires from ten to twelve minutes. This may vary a little, depending on the initial state of the converter (whether hot or cold) and also on the percentage of the elements present. As will be seen later, the percentage of silicon has the greatest effect on producing heat. With a low initial temperature, the elimination of the silicon is almost complete before the carbon is seriously affected, but there is a critical temperature where the relative affinities of silicon and carbon for oxygen are reversed, and when this is attained the silicon immediately ceases to have preference and the carbon seizes all of the available supply of oxygen. This continues till the carbon is reduced to about .03 per cent.

If the carbon is oxidized first, due to a high initial temperature, the "blowing" may be continued after the "drop" of the "carbon flame" and the silicon will be oxidized in preference to the iron itself.

In America this practice is not followed; it is considered better to eliminate the silicon early in the process, using scraps added to the charge or steam in the blast to reduce the temperature if necessary. The loss from "blowing" with converters of this size is from 8 to 10 per cent. Assuming the loss to be 8 per cent. and that the elements present as C., Si. and Mn., etc., do not exceed 5 per cent., we then have 3 per cent. of iron lost.

Analysis of the slag shows that three-quarters of one per cent. of the total output is held as "shot" and as this is not recovered, it represents a dead loss. Also about 1.8 per cent. is chemically united with the silicon in the slag. Then as losses in the slag we have approximately 2.5 per cent. To make up the total loss we have yet to account for 5 per cent. and this is mainly lost in being ejected from the nose of the converter, in the form of splashings.

The final temperature of the converter is about 1675° *C.* and may be accounted for thus:

Heat of metal on charging	1400° *C.*
Rise of temp. due to oxidization of elements	325° *C.*
Loss due to radiation	50° *C.*
Final temperature	1675° *C.*

The following table is taken from a recent work by Campbell on the manufacture of iron and steel, and shows the part played in the heat development by the different elements present. We have noted before that the oxydization of silicon had the greatest effect on producing heat. From the table we see that the surplus heat evolved by the oxidization of 10 kgs. of Si. is greater than that given off by 35 kgs. of C.

Calorific History of the Acid Converter.

Data:—1000 kgs. pig iron — Si. 1.0 p.c. — C. 3.5 p.c. Initial temp., 1400° *C.* Average temp., 1600° *C.* Loss 8 p.c. — metallic iron burned 2 p.c.

Specific heat at 1600° *C.* per kilo. liquid steel = 0.21 — liquid slag = 0.25 — lining = 0.25

CO and $N = 0.32$ and $CO_2 = 0.68$

Specific heat of air 100° to 1400° per kilo = 0.268

Net Heat Development.

	Calories developed.	Surplus.
Combustion of silicon—		
10 kgs. Si. + 11.4 kgs. O = 214 Si. O_2 =	64140	
11.4 kgs. O = 49.6 kgs. air absorbing		
49.6 × 0.268 × 1300 =	— 17280	46860
Combustion of iron—		
20 kgs. Fe + 5.7 kgs. O = 25.7 Fe O =	23460	
5.7 kgs. O = 24.8 kgs. air absorbing		
24.8 × 0.268 × 1300 =	— 8640	14820
Combustion of carbon—		
7 kgs. C. + 18.7 kgs. O = 25.7 kgs. CO_2 =	56930	
28 kgs. C. + 37.3 kgs. O = 65.3 kgs. CO =	68600	
56 kgs. O = 243 kgs. air absorbing		
243 × 0.268 × 1300 =	84830	40700
Total surplus heat developed		102380

Calorific Capacity of the Products.

Wt. × specific heat at 1600° *C.*

920 kgs. liquid steel × 0.21	= 193.2
150 kgs. liquid slag × 0.25	= 37.5
50 kgs. lining × 0.25	= 12.5
25.7 kgs. CO_2 × 0.68 × ¾	= 13.1
65.3 kgs. CO × 0.32 × ¾	= 15.7
244 kgs. N × 0.32 × ½	= 39.2
Total capacity for 1° *C.*	311.2

Theoretical rise in temperature $= \frac{102380}{311.2} = 329°$ *C.*

With the metal in converter brought to a proper condition, it is ready to be poured into ingot moulds. First the converter is tipped over and the blast shut off; the converter is now further tipped, allowing its contents to run into a ladle. During the operation the "spiegel" is added. The "spiegel" is a pig iron containing about 12 per cent. of Mn. For every ten tons of rail steel, about one ton of "speigel" is used; this gives enough manganese to roll well and sufficient carbon to confer the necessary degree of hardness. This "spiegel" is melted and prepared in a cupola near at hand. The ladle into which the molten steel from converter is poured, is mounted on wheels and rests on a track supported by the horizontal arms of a hydraulic crane. When the ladle is filled, the crane is elevated vertically, then it swings round till its horizontal arms engage with other projecting structural work, on which rests a track.

The track on crane arms and that on structural work now form a continuous way over which the mounted ladle is pushed by means of a hydraulic cylinder and ram, located behind ladle on crane arms.

The ladle is so constructed that the metal is poured from the bottom; this is accomplished by having a small hole in bottom, the cover of which is operated by a lever outside.

TO FILL THE INGOT MOULDS

The moulds, each mounted on a little car, are run beneath the ladle and as they come opposite the hole in ladle, the operator raises the lever, allowing the molten metal to run out.

Besides forming a very convenient method of filling the moulds, the hole in bottom serves another purpose. The slag being lighter than the metal, rises to the top; hence pouring from the bottom serves to make the separation almost complete.

The ingot moulds have an inside base measurement of 19″x 19″ and are 17″x 17″ at the top by 5′ 10″ long. They are made of cast iron, about 2½″ thick, and each mounted on a little car. The car is so constructed that its top forms the bottom of mould. On the sides of moulds are cast projections which aid in removing the mould from ingot.

The string of moulds, now filled, are coupled to a locomotive and drawn out on a siding where they are allowed to remain until the metal solidifies sufficiently to handle. When this condition is attained, the string of moulds are drawn over to the "stripper." The purpose of the "stripper" is to remove the mould from the ingot. This device resembles somewhat a travelling crane, in that it runs along on a track above and is operated by electricity in a similar manner. In place of the hoisting chain we have two long arms hanging down, which can be raised or lowered; through the lower ends of these arms are holes which are made to slip over the projections on side of mould.

To remove the mould the stripper is brought directly over the ingot and the holes in hanging arms are slipped over projections on side of mould; then a central arm is lowered to bear firmly on the ingot; with this central arm pressing down, the side arms are elevated, carrying up the mould, leaving the ingot on car. The ingot is still red hot but owing to the unequal condition throughout, it must be further treated before being passed to the bloom mill.

With the moulds now removed, the ingot is mechanically picked up by a travelling crane and taken to the soaking pits, nearby. These "soaking pits" are simply fire brick enclosed, reheating furnaces. They are twenty in number and located below the floor level, the sliding door on top being mechanically operated. Each of the pits has a capacity of eight ingots. The temperature is kept at from 2200° to 2300° Fahrenheit. The fuel used is natural gas, which is piped from West Virginia.

The ingots are allowed to remain in "soak" upwards of two hours. When ready to be removed, the sliding door on top is drawn back and a crane with a grappling device is lowered from a track above; the grappling device securely grips the ingot, and is then elevated. This crane deposits the ingot in the ingot carriage, which runs on track beside the pits. The ingot carriage conveys the ingot to the bloom mill; it is operated by electricity, the conducting wire being below and between the rails. This carriage and its run-way is so designed that when the carriage reaches the bloom mill end of its travel, it is caused to partly overturn, throwing its burden on the mill table. The centre of gravity of the car has been changed by this unloading and it falls back on track, ready to make another trip. The bloom mill tables are two in number, one on each side of the mill. Each consists of a stiff outer frame about 18′ long and 6′ wide. Between the sides and across the width, run rollers. These rollers are about 12″ in diameter and are spaced about 20″ apart. Their purpose is to give motion to the ingot, the driving force being supplied from a small reversing engine, through spur and level gears. This little reversing engine is controlled by the "roller" so that he always has the travel of ingot under control.

The power for the main drive of the bloom mill is supplied by an Allis-Chalmers compound Corliss engine, developing upwards of 2500 horse-power. This engine is direct connected to the rolls and runs at about 80 *R.P.M.*

This mill is known as a "three high" mill and takes its name from the fact that it consists of three rolls placed one above the other. By this arrangement the main driving engine does not have to be reversed at every "pass." Instead the ingot is started through the first pass at the bottom; as soon as it passes through, it falls on the table on the other side. This table is now made to elevate, bringing the ingot to right height to enter upper "pass."

The rollers on this table are now set running in proper direction and the ingot is passed through. In the meantime the "near" table has been elevated and receives the ingot. This table is now lowered and during the lowering operation the ingot is mechanically shifted and placed in line for next "pass."

In all, the ingot is given seven passes and is reduced from a 19″x 19″x 17″x 17″ section to 8″x 8″. The lifting and lowering mechanism of the table is operated by hydraulic power, the machinery being all below the floor level, and controlled by the "roller."

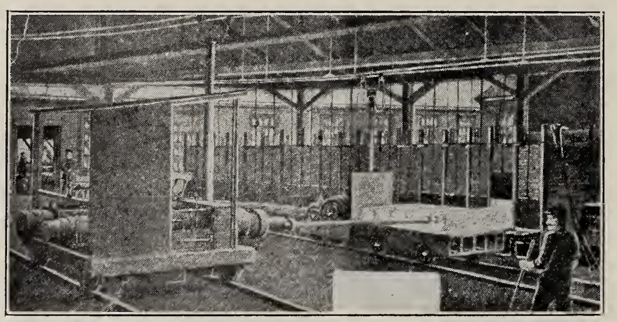
From the bloom mill the reduced ingot is passed along over carrier rolls to the shears, where the "crop end" is cut off, and where it is cut into "blooms" of the right length.

The "crop end" being low grade, due to piping and to impurities rising to top of mould, is of no further use here, and so is allowed to slide down a shute, where a car waits to receive it.

During the "bloom mill" rolling the metal has cooled considerably, so before the blooms are sent to the "roughing mill" they must be reheated. The bloom still on the line of roller carriers is conveyed to the end of the line. Here there is a switch, the purpose of which is to direct the bloom to one or the other of the two roughing and finishing departments. At the end of the line a small car receives the bloom. This car is capable of carrying about four blooms. With the car in position, the operator throws into motion a mechanism which shoves the bloom off the carrier rolls and on to the car. This car runs along on a track parallel to the row of reheating furnaces. These furnaces are of the ordinary brick enclosure type, having doors on either side; one side known as the charging end and the other the withdrawing.

To take the bloom from the car and place it in the furnace, a charging car is employed. This operation is shown in illustration. The charging car runs on a track parallel to bloom car track but at a distance from the furnaces greater than that of bloom car track. Thus the bloom car travels along between furnaces and charging car.

The motive power of charging car is electricity, but the rest of the mechanism is operated by air. To charge the furnace, the charging car is run opposite the bloom car, which has been properly placed opposite the door of furnace. The door is balanced so that by pulling a chain the operation of charging car may easily cause it to slide up. With the furnace door open, the long arm, shown in view, is made to move out, shoving the bloom into the furnace. The bloom is allowed to remain here until the desired temperature is reached, when it is withdrawn or discharged from the other side of furnace and sent to the roughing mill.



Method of charging retreating furnace

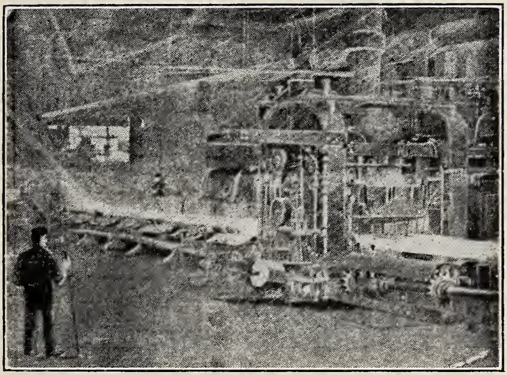
The discharging is accomplished by the aid of a "drawing car," resembling somewhat the "charging car," the essential difference being that on the long projecting arm there is a grappling device which is made to enter the furnace and draw the bloom out on to the bloom car.

On reaching the roughing mill table the bloom is mechanically removed from car and placed on table.

The roughing mill is also of the "three high" type, direct driven from a horizontal vertical Allis-Chalmers compound Corliss engine of about 2000 horse-power. The auxiliaries of this mill, including the lifting and lowering mechanism of tables, are operated similarly to the bloom mill auxiliaries.

Here the bloom is roughed to a section approximating that of the desired rail. This requires five passes.

Leaving the roughing mill it is carried along on a straight line of roller carriers to the intermediate mill, where it is given five passes. The intermediate mill is also of the "three high" type, but the lifting table is of a somewhat different design. Instead of the whole table elevating, it is pivoted at one end, that part being nearest the mill raising and lowering.



Rolling the Rails

The rail has now in process of rolling reached a considerable length, probably sixty-five feet, and so to economize in floor space and for other mechancial reasons, the semi-finished red-hot rail is made to run up a shute, as it takes the intermediate passes. On the last pass it is again allowed to go on the line of roller carriers and is delivered to the cooling tables. This cooling process has been made necessary in recent years by the increased size of the rails rolled. In former years the practice was to pass the rail direct from the intermediate to the finishing mill, but as larger sections were required, this practice did not give good results. After much experiment, the cause was found to lie in the fact that the larger rail section held the heat longer and so was being finished at a higher temperature. To overcome this, the cooling table was designed and located between the intermediate and finishing mills.

Owing to the fact that a greater amount of metal and heat is contained in the head of the rail than in the flange and web, the cooling, under ordinary conditions, would be unequal throughout. To guard against this, each rail is laid on the cooling table on its side, with its head against the flange of the rail in front of it, the exchange of temperature between the adjacent parts being such as to cause all parts of rail section to cool off at approximately even temperature. Each rail remains on the cooling table from three-quarters to one-and-a-half minutes, depending on the size of the section; it is then passed to the finishing rolls, where it is brought to exact size. This cooling process is said to give a heavy rail, in every way as satisfactory as the light rail of former years.

After leaving the finishing rolls, the rail is passed along by roller carriers to the "hot saws," where it is cut into the required length, the rails being cut somewhat longer than the finished length to allow for contraction in cooling. These hot saws are three in number, about thirty inches in diameter, and are mounted on a mandrel about seventy feet long, the saws being spaced apart a distance corresponding to length of rail required. This device is so designed that the mandrel carrying saws may be made to swing up or down, about a pivot. The saws are kept running all the time and as a rail comes into position the mandrel is caused to swing down, the saws cutting the rail into desired length.

Leaving the "hot saws," the rail now passes to the "hot beds." Here the rail is allowed to remain until cool enough to handle. The "hot bed" is simply a frame made of rails placed at right angles to run-way. As the rail comes down the run-way it is mechanically pushed over on the bed.

After cooling here, the rail is sent to the straightening department, where it is passed through a press, the same being allowed to strike it where necessary to remove bends.

From here it is passed over roller carriers to the drilling machines where the bolt holes in web are drilled. The burrs are then removed and the rail is ready for inspection before being shipped.

REFINING OF SILVER BULLION CONTAINING ARSENIC AND ANTIMONY

B. NEILLY, '07

The following work was suggested by a paper on "The Refining of Gold Bullion," by Dr. T. Kirk Rose, in 1905, and found in Vol. 14, Transactions of British Institute of Mining and Metallurgy.

In his experimental work Dr. Rose did not confine himself wholly to gold bullion but proceeded to show that even in the case of silver bullion the base metals could be oxidized off by passing a stream of oxygen through the molten metal. In his early work he used only pure oxygen but in subsequent experiments he used air and found the results obtained were quite as satisfactory. In the case of gold he found that by this method it could be reduced to the pure state with very small losses.

The writer applied Dr. Rose's method to the refining of silver bullion containing arsenic and antimony, but found that it required very careful manipulation to prevent spitting. The pipe immersed in the molten metal gradually corroded away; the end broke off suddenly and the pressure being reduced particles of silver were projected out of the crucible. In addition to this the method was slow. After passing a current of air through the metal until the fumes apparently ceased to come off it was cast and assayed only 90 per cent. silver. It was again melted down and air passed through. At the end of ten minutes no fumes were visible, but on withdrawing the pipe and allowing the air to play upon the surface copious fumes began to rise at once. This method was continued and from the results that follow it would appear that blowing on the surface rather than through the metal is much more satisfactory.

The apparatus at our disposal consisted of a crucible furnace No. 6 and a Cyclone crucible furnace with air blast as manufactured by Fletcher, Russel & Co. The bullion was fused in Battersea graphite crucibles and the air was conveyed by a rubber hose from a Root's No. 08 blower driven by one-half h.p. motor. To the end of the hose was attached a 22″ fire clay pipe ¼″ in diameter (inside measurement) to convey the air down to the surface of the metal. This then was suspended from above in such a way that it could be raised or lowered through a hole in the asbestos top to any required position.

In order to get rid of any nickel, copper or cobalt present along with as much arsenic and antimony as possible, it was decided to form a speiss. The bullion was melted down in the cyclone furnace at a temperature of about 1140° C. and iron in the form of nails added until they were unattacked by the arsenic and antimony present.

The crucible was then removed and cooled suddenly. Under these conditions the speiss separated cleanly from the bullion. The bullion was again melted down at a temperature of about 1090° C. with enough flux composed of sand and borax (2:1) to form a thin covering on the top of the molten metal. The air with sufficient pressure to cause a depression of say one-quarter inch on the surface was then blown on the metal until the arsenic first and then antimony were all oxidized off and the bullion pure.

This end point is easily determined. Samples are dipped out and after cooling, hammered. If they are inclined to be brittle to the least degree the metal still contains some impurities. Even a small fraction of one per cent. impurity will cause it to crack. Again on becoming pure the molten metal changes from a white to a clear sea green in color.

The bullion used in the first five experiments assayed as follows: Silver, 80.9 per cent.; arsenic, 7.5 per cent.; antimony, 9.6 per cent. Nickel and cobalt not determined.

Experiment No. 1.

It was in this experiment that Dr. Rose's method of passing the air through the molten metal was tried with the results as before stated. At the end of 2 hours, 10 minutes, the silver content was only 90 per cent. The air was then blown on the surface and at the end of another 3 hours the metal was pure.

Summary—

Silver content of original bullion, 1974 × 80.9 =		1596.9 grs.
Final wt. bullion		1573.0 "
Loss from all causes		23.9 "
Loss up to end of speissing		15.5 "
Total loss of silver	1.5 p.c.	
Loss up to end of speissing	0.9 "	
Loss due to volatilization, slag, etc.	0.6 "	

Since the speiss obtained weighed 326 grs. and assayed 0.47 p.c. it contained 1.5 grs. and the other 14 grs. must be charged to spitting and other forms of mechanical loss.

Experiment No. 2.

General method used and time required for blowing was 3 hours and 40 minutes.

Summary—

Silver content of original bullion, 2750 × 80.9 =		2224.7 grs.
Final wt. of pure silver		2207.54 "
Loss due to all causes		17.16 "
Total loss in silver	0.77 p.c.	
Loss up to end of speissing	0.11 "	
Loss due to volatilization, slag, etc.	0.6 "	

Experiment No. 3.

Used general method but tried to speiss with magnetite without success, in the end having to remove it. Again used pure borax as flux. Time required for blowing was 3 hours 40 minutes.

Summary—

Content of original silver bullion, 2000 × 80.9 =	1618 grs.
Final wt. pure silver	1602 "
Total loss from all causes	16 "
	= 0.98 p.c.

In this case the crucible was badly corroded and no doubt some of the loss occurred in removing the magnetite.

Experiment No. 4.

In this case did not speiss but began blowing at once. At the end of 1 hour and 20 minutes it assayed 87.8 p.c. and at the end of 4 hours it ran 96 p.c. It still required 2 hours to bring it to the final state.

Summary—

Silver content of original bullion, 2290 × 80.9 =	1852.6 grs.
Final wt. pure silver	1836.2 "
Total loss for all reasons	15.4 "
	= 0.9 p.c.

The total time required here was 6 hours. From this it would appear that the speiss is useful if only for the removal of some of the antimony.

Experiment No. 5.

Followed general plan carefully assaying the slag and speiss. The time required for blowing was 3 hours, 45 minutes.

Summary—

Silver content of original bullion, 2509 × 80.9 =		2029.7 grs.
Final wt. of pure silver		2007.7 "
Total loss for all reasons		22 "
		Total loss = 1.08 p.c.
Loss due to speiss	.08 p.c.	
Loss due to slag	.13 "	
Loss due to volatilization, etc.	0.87 "	

In this case the crucible broke and in recovering the bullion there must have been some mechanical loss.

Experiment No. 6.

General method used. The bullion in this case assaying 88.7 p.c. silver and containing as its impurity mostly arsenic with very little antimony. Time required to blow, 3 hours.

Summary—
Silver content of original bullion, 2530 × 88.7 = 2244 grs.
Final wt. of pure silver .... 2222 "

Loss for all reasons .... 22 "
Total loss .... 0.98 p.c.
Loss due to speissing .... 0.13 "

Loss due to volatilization, slag, etc. .... 0.85 '

Experiment No. 7.

This was by all odds the most careful and complete determination made. Starting with a bullion assaying 80.15 p.c. silver, the impurities being arsenic and antimony, the general method was used.

Summary—
Silver content of original bullion, 2546 × 80.15 = 2041 grs.
Final wt. of pure silver .... 2025 "

Total loss for all reasons .... 16 "
Total loss = 0.79 p.c.
Loss due to speiss .... 0.08 p.c.
Loss due to slag .... 0.12 "

Loss due to volatilization, etc. .... 0.59 "

In the first five experiments the bullion after speissing assayed between 83.2 and 83.8 p.c. and on remelting and adding more iron it was found impossible to raise the silver content. The same remarks apply to the bullion containing mostly arsenic as its impurity after being speissed up to 94.02 p.c. Apparently the affinity of iron and silver for arsenic and antimony is equal at this stage.

Summarizing the results without taking into consideration Experiment No. 1, it is found that the average total loss, allowing for everything = 0.88 p.c. To this say the speiss contributed 0.1 p.c. and the slag 0.12 p.c. Then the loss due to volatilization and to the fact that certain small amounts are carried over mechanically, is placed at 0.66 p.c.

No attempt was made to collect the flue dust but on disconnecting the furnace and scraping out the flue a sample of 200 grs. was collected that assayed 2.2 p.c. silver. On volatilizing some of this in an open tube small particles of metallic silver were left behind, showing that some of the silver had been carried over mechanically.

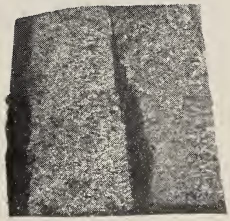
In Plattner's Rostprogesse, losses due to the oxidization of silver at high temperatures are dealt with largely.

First he records that in passing hydrogen or carbon dioxide over silver at high temperatures there was no loss. In heating silver exposed to air in the presence of arsenic and antimony the losses were not so high as where sulphur, iron or copper was present. He reasoned that the silver on being heated first changes to the oxide. Now when arsenic and antimony are present they unite with the silver oxide to form arsenates and antimonates and are themselves oxidized, thus protecting the silver.

After the arsenic and antimony have been removed the loss becomes heavy. Dr. Rose found that on passing oxygen through 10 grs. of molten silver for 40 minutes the loss was as high as 8 p.c.

Plattner exposed a finely powdered smaltite ore carrying about 50 ozs. to the ton in silver, to a high temperature and collected the flue dust in a long pipe. Two feet from the furnace residue assayed 10 p.c. silver value of ore; 12 feet, 4 p.c.; 36 feet, 2½ p.c.; 98 feet, 1-10th p.c. In this dust he found a portion of the finely divided ore and on investigating concluded that the mechanical loss was proportional to the amount of finely divided material carried over. Later he mixed finely divided silver with powdered quartz and his loss was over 10 p.c.

Bullion blown, 1 hr., 20 min.
Assays
Ag.—88.33% As.—2.3%
Sts.—9.54% by diff.



Fracture of Silver Bar
Assaying
Ag.—99.2%

After many experiments such as these, Plattner concluded that the loss due to volatilization and mechanical means was influenced largely by the amount of surface exposed.

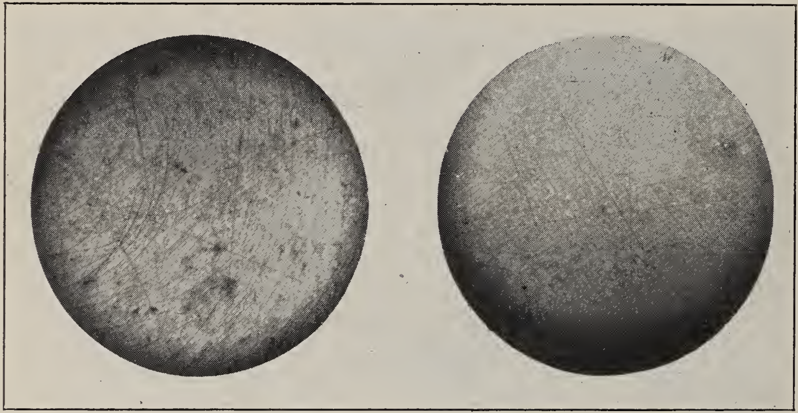
Now in the method described in this paper only a thin covering of acid slag was used and the surface exposed is small since it depends wholly on the amount of slag displaced by the air blast.

Thirty per cent. of the total loss was due to the speiss and slag. This could be recovered by retreating in the blast furnace. The remaining 70 per cent. of the total loss is charged to volatilization and mechanical means and it would appear from

Plattner's experiment with flue dust that this could be greatly reduced by the use of a dust chamber.

No difficulty was experienced in refining the bullion to 99.985 p.c. and since the loss is exceedingly low and the cost of refining small, it looks as though it might be made use of commercially.

The photos below were obtained by polishing and etching samples taken from the bullion at different stages. The dark spots represent the impurities (arsenic and antimony) and the lines extending across the face are due to imperfections in polishing.



Original Bullion
Assays
Ag.—80.9% Sts.—9.6%
As.—7.4%
Co. and N, not determined

Refined Bullion
Assays
Ag.—99.985% As.——
Sts.——

PRESIDENT'S VALEDICTORY

Gentlemen:—As retiring President of the Engineering Society, it gives me great pleasure to thank you for your hearty co-operation during the past year. It has been a year full of new undertakings but one in which we have had a fair measure of success, and with your permission I will review the work covered:

The appointment of a paid secretary, which has long been suggested by past Executives, has at last been consummated through the co-operation of the Faculty Council. By this appointment a great increase in the variety and sale of supplies has been rendered possible and the Supply Department under the new conditions has been placed on a working basis.

The new monthly, "Applied Science," now replaces the old "Transactions of the Engineering Society," and from the hearty reception it has received from undergraduates and graduates, it fills a long-felt want. Through this publication future Executives will find the formation of an employment bureau made easy, and in fact some little preparatory work along that line has been done already.

During the past session sectional meetings, rendered possible under the changed constitution, have been held and have been well attended, a great many undergraduate papers being brought out by this means. The telephone question, which has been an issue in so many past elections, is now solved by the employment of a call boy, paid by the Society.

The annual dinner, held this year for the first time on University ground, was an unqualified success.

A new departure, which hardly falls under the Society's work, has been instituted in a manufacturers' exhibit which it is hoped will be broadened by the incoming Executive. Certain exhibits have been already secured and will be mounted and placed in the halls before the coming fall. These will no doubt be of great interest to all the undergraduate body.

The Faculty Council have been impressed with the desirability of having smoking and reading rooms in the new buildings which are to be erected, and I believe it is their intention to provide these.

The constitution of the Society has been revised and it is now believed to be in permanent condition. Two changes worthy of note are, the year Representatives being thereby Presidents of their years, and the President of the Society, the representative of the students of the faculty on the Executive of the Undergraduates' Parliament. By this means it was felt that the faculty would be brought in closer touch with the University and it was also desirable for the Society to have an intimate connection with the year organizations. As a member of the Executive of that Parliament, the President will be enabled to watch over the interests of the undergraduates in the faculty, and the year representatives as presidents of their respective years will produce harmony between the Society and the year organizations.

Much of the work which has been accomplished during the past year has been due largely to the strong Executive Committee with whom it has been my privilege to be associated. Your thanks is due them for the earnest and efficient manner in which they have discharged the duties of their several offices.

In closing, allow me to thank you for the honor you have done me in placing me in this position, and I sincerely hope that during the past year I have in some small measure merited the confidence you placed in me last spring.

I have much pleasure in presenting to the Society their President-elect for 1908-09, Mr. R. J. Marshall.

Yours sincerely,
THOMAS H. HOGG.

TREASURER'S REPORT

Mr. President and members of the Engineering Society: I beg to make the following report of the financial standing of the Society on the completion of the business for 1907-08:

Receipts.

Resources realized from 1906-07—		
By cash on hand, April 1st, '07	$331.67	
By advertisement pamphlet No. 20	241.00	
By outstanding account received	20.60	
By percentage of fees, '06-'07	465.00	
		$1,058.27
Receipts for business, '07-'08—		
By part of fees '07-'08	665.00	
By annual grants 1907 and 1908	100.00	
By past fees, held by faculty	399.75	
By other fees	2.00	
		1.166.75
By receipts from annual dinner		821.74
By sale of supplies		5,120.53
By subscriptions to Applied Science		58.00
		$8,225.29

Disbursements.

Liabilities incurred by previous executive—		
To presentation to retiring president	$ 50.00	
To damages at elections, March, '07	47.00	
To other bills	32.98	
To cost of pamphlet No. 20	870.87	
		1.000.85
Running expenses, '07-'08—		
To representatives to other colleges	80.00	
To annual elections	89.50	
To printing and stationery	34.27	
To expenses of meetings	42.10	
To flowers, phone and sundries	113.76	
		359.63
To cost of annual dinner		819.41
To purchase of supplies	4,856.25	
To expenses of supply department	221.44	
		5,077.69
To cost of Nos. 1, 2 and 3 Applied Science		637.98
Cash balance, May 1st, 1908		329.73
		$8,225.29

Resources.

Cash balance	$329.73
Remainder of fees, '07-'08	56.00
Accounts due supply department	139.18
Advertisement due Applied Science	290.22
Cost price, stock on hand in supply department, March 15th, 1908	1,269.31
Other debts due Society	60.00
	$2,144.44

Liabilities.

Outstanding accounts in supply department	150.00
Other outstanding accounts	84.75
Estimated net cost of Nos. 4, 5 and 6 Applied Science	285.00
Surplus	1,624.69
	$2,144.44

It will be seen that the Society has handled a turn-over of $8,000 on a capital of a few hundred and the Executive has been considerably hampered in its operations in consequence, especially in starting new enterprises.

The actual resources of the Society at the beginning of the year amounted to $512.77 after meeting existing liabilities.

Our thanks are due to the Secretary of the Faculty for the accommodation that has been extended to us in carrying through the business of the year.

We have endeavored to place the Society on a more satisfactory footing and the net resources as shown in statement terminating this year's business are $1,624.69, or an increase of $1,111.92. The larger part of this is to be found in stock on hand, which has necessarily been considerably increased with the larger assortment of supplies now carried. It will also be noted that the pamphlet, which has heretofore been carried into the business of the following year, has been replaced by "Applied Science," which is paid for as it is issued, a much more satisfactory principle. With increased advertising and subscription lists, the loss on publications will also in all probability be greatly reduced now that this periodical is fairly established.

The Faculty have agreed to collect from each student a fee of one dollar for the Engineering Society instead of giving the Society 75 per cent. of the so-called library fee and this will mean a considerable increase in revenue.

We therefore hope that, so far as money can be used to strengthen the position of the Society, following years will find themselves well equipped.

A. F. WILSON, Treasurer.

AUDITORS' REPORT

We hereby declare that we, the undersigned Auditors, have examined all vouchers and audited all accounts and found them to be correct.

Owing to the extent and complex nature of the business handled by the supply department, we beg to recommend that in future a more elaborate and systematic set of books be kept in this department, and owing to the growth of the business, that a professional auditor be employed, as it takes so much time for the lay mind to become conversant with all the details.

We beg to recommend the improvement in the system of book-keeping employed in the general accounts over last year.

Auditors
S. R. CRERAR
GEO. E. QUANCE

Toronto, May 4th, 1908.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

Published Monthly during the College year by the University of Toronto
Engineering Society.

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Editorial

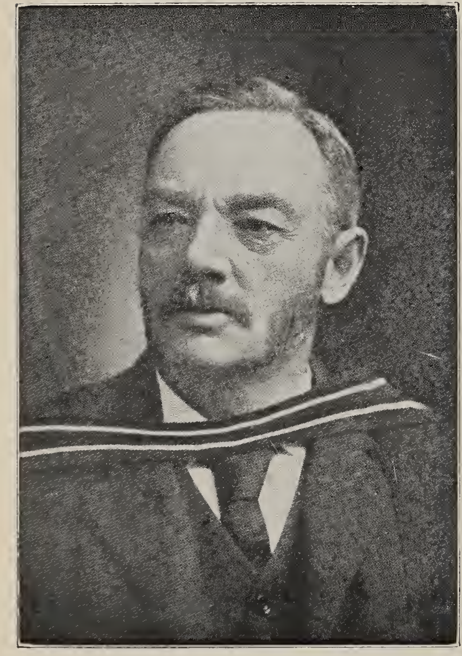
This issue completes the first volume of "Applied Science." The step from a yearly to a monthly publication was taken only after careful consideration, and in spite of considerable pessimistic advice to proceed slowly, that neither material nor money was available to bring the venture to a successful issue.

Our optimism was justified. Financially, we are in a better position than last year. As to the quality of the contributed articles, our readers may be left to judge. We wish to take this opportunity of thanking our contributors, both graduates and undergraduates, for the valuable assistance they have afforded.

One of the chief reasons of our existence is to bring and keep the graduate more closely in touch with the institution. In this Applied Science has been eminently successful.

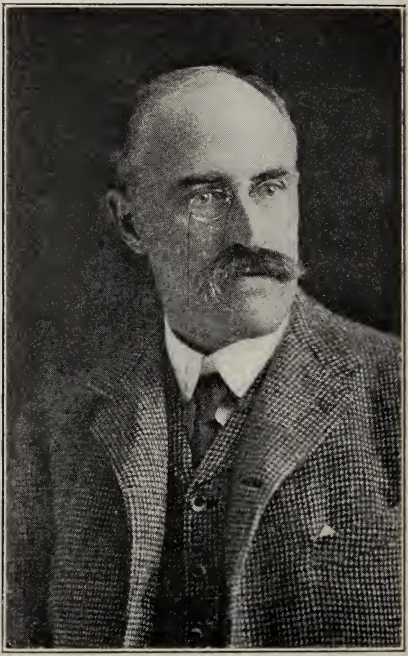
To the Graduates

Our subscription list has reached a very healthy state. However, a great number of men have neglected to send in their subscriptions. This has been due to carelessness. During the whole year we only met one graduate who felt he really could not afford the sum of fifty cents necessary to become a paid subscriber. Times are bad, but the financial stringency is hardly that severe. The revenue from subscriptions is only a small portion of our income. What we want is your assistance with the advertisers. At every opportunity boost Applied Science. If you ever do any business with our advertisers tell them where you saw their advertisement. It will help us all. Patronize our advertisers where possible. In a number of cases the concerns are managed by our own men. Next year we shall have a fair start and each number will be issued regularly, beginning in November and finishing in April.



J. Galbraith

President Canadian Society of Civil Engineers



W. F. Tye

Vice-President Canadian Society of Civil Engineers

It affords us much pleasure to print the following letter from

Canadian Society of Civil Engineers

T. Kennard Thomson, urging all School graduates and undergraduates to connect themselves with the Canadian Society of Civil Engineers. For some time there was a tendency to regard this body as an Eastern institution and of little interest to Western engineers. Lately, however, it has become truly national. Branches have been established in various centres, interest awakened, and strength gained which will go far towards raising the standard and furthering the interests of the profession generally in Canada. This year, quite by accident, three important executive positions are held by Toronto University men. Dean Galbraith is president; W. F. Tye, of Montreal, and G. H. Duggan, of the Dominion Coal Co., Glace Bay, are vice-presidents. A biography of Mr. Tye appears in "What Our Graduates Are Doing." We regret that it was impossible to procure one of Mr. Duggan.

New York, May, 1908.

" To the Graduates and Undergraduates of
The School of Practical Science.

Gentlemen:—

Every Canadian Engineer ought to belong to the Canadian Society of Civil Engineers just as every S. P. S. man ought to belong to the University of Toronto Engineering Society, and should keep all Societies of which he is a member posted as to his proper address to avoid losing good opportunities.

As our Dean, Dr. John Galbraith is now President, and two S. P. S. boys are Vice-Presidents of the Canadian Society of Civil Engineers, it seems to be an appropriate time to join.

Will you not write to C. H. McLeod, Esq., Sec. Can. Soc. C. E., 413 Dorchester Street, Montreal, Que., for application blanks and list of members ?

Yours sincerely,

J. KENNARD THOMSON.

WHAT OUR GRADUATES ARE DOING

Biography

Mr. William Francis Tye was born at Haysville, Ont., March 5th, 1861. He was educated at Ottawa University, and at the School of Practical Science, Toronto (1878 to 1881), and entered railroad service in 1882. From then until 1885 he served successively as rodman, leveler, transitman on location, and afterwards as assistant engineer on construction of the Canadian Pacific. During 1886 and 1887 he was transitman and assistant engineer on the St. Paul, Minneapolis and Manitoba. The next year he served as Engineer of Track and Bridges on the Tampico Branch of the Mexican Central. In 1890 he was locating Engineer of the Great Falls and Canada Railway in Montana, and in 1891 and 1892, Engineer in charge of location and Division Engineer of the Pacific extension of the Great Northern. For about two years he was in the west as engineer in charge of the change of gage of the Alberta Railway and Coal Company's road. In 1895 he was Chief Engineer of the Kaslo and Slocan Railway, and for four years following 1896, he held a similar position on the Columbia and Western. In 1900 Mr. Tye became Chief Engineer of Construction of the Canadian Pacific, in June, 1902, was appointed Assistant Chief Engineer of the system, and in May, 1904 was appointed Chief Engineer. In February, 1906, he resigned to take up the construction of electric tramways and power developments on his own account.

He is now Vice-President and Chief Engineer of the Canada Electric Syndicate, Limited, who are undertaking large power and tramway installations in Mexico.

Mr. Tye is a member of the American and Canadian Societies of Civil Engineers, and of the Maintenance-of-Way Association, and is a member of the St. James Club of Montreal, and of the Manitoba Club of Winnipeg.

R. W. Thomson, '92, has returned from South Africa and is now in charge of the Red Rock mine at Haileybury.

E. V. Neelands, '00, has resigned as resident manager of the Black Queen Mining and Reduction Co. at Crystal, Col., to take charge of the Ruthellan mine at Lake City, Colorado, for English capitalists.

T. K. Thomson, '06, has removed his offices from the Park Row Building, New York, to the Hudson Terminal Building. His business card gives the following record of experience: Ten years in structural steel with our best bridge companies, etc, starting as draughtsman and rising to chief engineer; as bridge engineer for railroad, had charge of the construction of 129 bridges; ten years in foundation work with best contractors, eight of which was chief engineer for well-known contractors; designed many of the largest and most economical caissons, and been in air chambers over 2,000 times; retained on over one dozen New York skyscrapers.

Geo. M. Bertram, '01, has been appointed local manager at Joplin, Missouri, for the Sullivan Machinery Co.

J. L. Morris, C.E., our first graduate, and W. J. Moore, '06, have formed the firm of Morris & Moore, land surveyers and architects, at Pembroke, Ontario.

C. H. Hutton, '08, is with the Dominion Electric Co.

D. J. McGugan, '07, is with H. H. Depew, '04, at the Crow's Nest Light, Heat and Power Co.'s plant at Fernie, B.C.

Mr. Norman Gibson, B.A.Sc., '01, of Winnipeg, has been appointed engineer of construction for the city of Brandon to superintend, under City Engineer Shillinglaw, the construction of the new cement bridge over the C.P.R. tracks and the Assiniboine River at First Street.

Mr. W. S. Gibson, B.A.Sc., '04, paid us a visit last week. Mr. Gibson has just returned from a two years' stay in Ceylon Island and Southern India, where he has been engaged with extensive experiments connected with the pearl fisheries.

R. E. W. Hagerty, '07, C. Murdoch, '06, J. A. Walker, '08, and a few others are going to the Yukon gold fields for the summer.

H. O. Hill, '07, is with the Riter Conley Co. at Allegheny, Pennsylvania.

E. D. Wilkes, '07, is with the Department of Public Works, Saskatchewan.

Great interest is being taken in the work of F. C. Baldwin, '06, and J. A. McCurdy, '07, in their endeavor to solve the problem of aerial navigation. Both are meeting with a considerable measure of success, "Casey" being apparently in the lead. Applied Science and all the graduates wish them every success.

Trafford Jones, B.A.Sc., '06, has entered the services of C. H. Mitchell, following hydro-electric work. He spent last year at mining in British Columbia.

M. H. Baker, '06, is with Metcalf Engineering Company at Midland.

M. Bates, '06, and O. Rolfson, '06, are with Laird & Routley at Haileybury.

H. M. Hyland, '07, E. Harrison, '07, have gone west on D. L. S. work.

A. L. Harkness, '06, has returned to his old position with the Dominion Bridge Co. at Montreal after taking his B.A.Sc. course.

F. R. Anderson, '07, E. G. Hewson, '08, Chas. Ross, '06, W. C. Jepson, '06, are on the Welland Canal staff.

A. C. Spencer, '07, is taking a special course in Germany, devoting his attention to producer gas engines.

J. A. Stiles, '07, is with the city engineer's staff at London.

O. L. Flanagan is pursuing similar work at Guelph, while A. Kinghorn, '07, and J. L. G. Stewart, '08, are similarly employed at Toronto.

J. M. Wilson is resident engineer for the Wood Products Company's new plant at Haliburton.

A. F. Wilson, '07, has secured a position with the Chicago Tedephone Co.

The Canadian Cement and Concrete Association was organized in Toronto on the 20th of April, 1908. The new association will work along similar lines to its sister organization, the National Association of Cement Users, in the United States. There is a wide field of usefulness in Canada for the new association. Manufacturers, contractors, engineers and architects are eligible for membership. In spite of its recent formation, a very healthy membership has already been acquired. The president-elect is Peter Gillespie, lecturer on Theory of Construction, of Faculty of Applied Science, and the secretary-treasurer, A. E. Uren, '05, at present editor of the Canadian Cement and Concrete Review. The offices are at 62 Church Street, Toronto.

APPLIED SCIENCE

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TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Vol. 1 - New Series
" 1-21 - Old "

November, '07 to April, '08

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